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Rationale Document Supporting Revisions to Manitoba Surface Water Quality Objectives

Manitoba
Environment and
Workplace Safety
and Health

RATIONALE DOCUMENT SUPPORTING REVISIONS TO MANITOBA SURFACE WATER QUALITY OBJECTIVES

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SUMMARY

Surface water quality objectives were developed for application within Manitoba in 1976 in order to assist water quality management activities. These objectives underwent several minor revisions in 1979, then a number of major revisions were proposed in 1983. The revisions proposed in 1983 were circulated widely within Manitoba and Canada in order to solicit constructive criticism. The Clean Environment Commission convened a public hearing in November, 1984 to review the proposed revisions in a public forum and to ensure that all those likely to be affected by the changes had an opportunity to comment. The Clean Environment Commission submitted a report in September, 1985 to the Minister, Manitoba Department of Environment and Workplace Safety and Health discussing the findings of their review. This report contained a number of recommendations, only one of which pertained directly to elements of possible technical deficiency within the proposed revisions. The Clean Environment Commission recommended that these issues be re-examined. The following report discusses these areas of contention.

Additionally, new scientific information has become available such that revisions to the specific objectives for the parameters un-ionized ammonia, arsenic, cadmium, chlorine, chromium, copper, cyanide, lead, and mercury are warranted. Rationale is provided to support changes to the objectives for these materials. Minor changes are also warranted to the bacteriological indicator organism objectives for recreational waters. A discussion is included regarding the applicability to Manitoba of recent changes to the recreational water quality criteria in the United States.

Overall, the objectives for these parameters are less restrictive than previously recommended, while providing the same degree of protection as previously envisaged.

This document was circulated for review to numerous agencies and individuals including members of the Interdepartmental Advisory Committee on Water Quality Objectives, municipal and industrial corporations, staff within the Canada Departments of Environment and Fisheries and Oceans as well as the Manitoba Environment Council and the Clean Environment Commission.

Future revisions will continue to be proposed to the Manitoba Surface Water Quality Objectives as more experience is gained and as new scientific information becomes available.

TABLE OF CONTENTS

		PAGE
Summary		i
Table of Contents		ii
List of Tables		iii
List of Appendix		iii
1.0	Introduction	1
2.0	Re-examination of Unresolved Water Quality Objectives Areas In Accordance with the Recommendations of the Clean Environment Commission	2
	2.1 Mixing Zones	2
	2.2 Minimum Flow	3
	2.3 High Quality and Exceptional Value Water Designations	4
	2.4 Domestic Consumption Objectives for Fecal Coliform Bacteria	5
	2.5 The Definition of Toxic Substances and Nutrients with Regard to General Requirements for Water Quality	5
3.0	Differences Between the U.S. EPA and the CCREM Methods to Derive Criteria for the Protection of Aquatic Life	6
4.0	Revisions to Specific Numerical Objectives, Class 2: Aquatic Life and Wildlife	10
	4.1 Un-ionized Ammonia	13
	4.2 Arsenic	24
	4.3 Cadmium	26
	4.4 Chlorine	27
	4.5 Chromium	29
	4.6 Copper	31
	4.7 Cyanide	33
	4.8 Lead	34
	4.9 Mercury	36
5.0	Revisions to Specific Numerical Objectives, Class 5: Recreation, Category A: Primary Recreation	38
	5.1 Indicator Organisms	38
6.0	References	47

LIST OF TABLES

PAGE

Table 1: Available un-ionized ammonia chronic toxicity data base, listed in descending order of magnitude..... 20

Table 2: Identification of the 0.05 fraction of the un-ionized ammonia chronic toxicity data base, using cumulative probability analyses..... 22

Table 3: Percent un-ionized ammonia in total ammonia solutions for temperature and pH ranges of 0 to 30°C and 6 to 10 pH units, respectively (Emerson et al. 1975)..... 23

Table 4: 60% and 90% one-tailed upper confidence limits and corresponding sample size required to determine non-compliance with bacterial indicator organisms in recreational waters..... 45

LIST OF APPENDIX

PAGE

Review of Surface Water Quality Objectives For Manitoba. Manitoba Clean Environment Commission, September 1985..... 51

1.0 INTRODUCTION

Surface water quality objectives were developed for use in Manitoba in 1976 to assist in water quality management activities (Clean Environment Commission 1977). Considerable program evolution has occurred as experience was gained in this field and as new scientific knowledge emerged. Williamson (1983) proposed numerous revisions to this activity. These revisions were the subject of a public hearing convened by the Clean Environment Commission in November, 1984.

The Clean Environment Commission submitted a report to the Minister, Environment and Workplace Safety and Health in September 1985 with regard to the findings of their review. This report is attached in Appendix A. The Clean Environment Commission made eight recommendations. The majority of these recommendations pertained to administrative practises or reflected aspects of the program or program direction that the Department of Environment and Workplace Safety and Health highly favours as opposed to technical deficiencies. The Commission however, also recommended that the Department of Environment and Workplace Safety and Health, in conjunction with the Water Quality Objectives Advisory Committee re-examine a number of unresolved areas. These issues are discussed in the following Section 2.0.

During the public hearing process, the Water Standards and Studies Section advised the Clean Environment Commission that a number of activities were occurring internationally that were being monitored and that alterations to specific numerical objectives may be desirable in the near future. Principal among these were the development of new criteria by the United States Environmental Protection Agency for a number of parameters germane to Manitoba. Additionally, the Guidelines for Canadian Drinking Water Quality (Health and Welfare Canada 1978) are presently being reviewed and national water quality guidelines have been developed under the authority of the Canadian Council of Resource and Environment Ministers (CCREM 1986). Consequently, a number of revisions to specific numerical objectives are proposed. These are discussed in the following Section 3.0.

The document "Manitoba Surface Water Quality Objectives" (Williamson 1988) reflects many of the suggestions and recommendations received during the public review process conducted by the Clean Environment Commission in November, 1984. Many areas were revised to include information in order to better express the intended application and to editorially improve the text. The reasons for these alterations are hopefully self-explanatory and are not discussed here. Most revisions of this nature were forwarded to the Clean Environment Commission in January 1985 and are discussed in their September, 1985 report (Appendix A).

2.0 RE-EXAMINATION OF UNRESOLVED WATER QUALITY OBJECTIVES AREAS IN ACCORDANCE WITH THE RECOMMENDATIONS OF THE CLEAN ENVIRONMENT COMMISSION

2.1 Mixing Zones

The mixing zone section was altered substantially although, in all likehood, not to the extent that would alleviate all discord. Use of the mixing zone guidelines is pivotal to the practical application of water quality objectives through their use in assisting to develop effluent discharge limitations. Unfortunately, the factors that affect decisions concerning mixing zone configuration and size are unique to each site.

The statement that appeared to cause the most controversy was as follows: "the mixing zone should contain not more than 25% of the cross-sectional area/volume of flow at any transect in the receiving water during all flow regimes when the specific water quality objectives are applicable". This statement was replaced with "for those materials that elicit an avoidance response from aquatic life, the mixing zone should contain not more than 25% of the cross-sectional area or volume of flow at any transect in the receiving water. Should a proportion of the stream width greater than 25% be selected for these materials, the mixing zone could act similar to a physical barrier and effectively preclude the passage of aquatic life".

Further, the statement "the 96 hr LC_{50} for indigenous fish species should not be exceeded at any point in the mixing zone" was

replaced with "the mixing zone should not be acutely lethal to aquatic life passing through the mixing zone. Thus, acute lethality within the mixing zone is a function of the concentration of a toxic material and the duration of exposure".

Other changes to the mixing zone guidelines were largely for editorial or organizational purposes. Thus, the clear intent is that mixing zone guidelines are necessary to limit the loss of value of water quality resources in areas in the vicinity of effluent outfalls. Aquatic life and other uses are not offered protection in these areas since the numerical water quality objectives do not apply. Thus, principal consideration must be given to avoiding discharge plumes containing materials at concentrations that disrupt the normal movement of aquatic life passing through such areas. Further, aquatic life are exposed to materials in the mixing zone for only a short period of time. The conditions within the mixing zone should therefore not be acutely toxic or to otherwise cause "an irreversible organism response" for this period of time.

2.2 Minimum Flow

Minor changes were made to the sections pertaining to minimum flow. A statement was added to recognize the fact that flow in many streams within Manitoba is managed to such an extent that historical flow data cannot be used to statistically calculate the average minimum seven day flow with a probability of recurrence of once in ten years. The minimum flow must then be derived from the specific management policy for that stream as determined by the professional judgement of staff of the Water Resources Branch, Manitoba Department of Natural Resources.

An editorial change was also made to clarify the intent that in cases where intermittent streams do not contain the minimum flow of 0.003 m^3/s, conditions should not deteriorate to such an extent that the objectives within downstream water bodies are exceeded.

2.3 High Quality and Exceptional Value Water Designations

A statement was added to the High Quality Designation to specify that where such a designation included the protection of aquatic life and wildlife, all life stages of all resident species likely to be affected would be protected. Consequently, the numerical objectives for specific parameters may be adjusted to reflect this additional degree of protection. The list of attributes worthy of the High Quality and Exceptional Value designations was expanded. Canadian Heritage Rivers was added to both designations and uses such as domestic consumption was added to Exceptional Value waters.

Other revisions were not considered for this section, even though it is expected that consensus amongst resource harvesters has not been achieved. The Department of Environment and Workplace Safety and Health is of the opinion that certain pristine areas of the province are worthy of the additional water quality protection offered by these designations. These designations recognize that in certain areas of the Province, degradation of the existing ambient water quality is not desirable. Notwithstanding the fact that the maximum acceptable objectives specified in Section 2, Manitoba Surface Water Quality Objectives, will, in the best scientific judgement of the Department of Environment and Workplace Safety and Health, adequately protect Manitoba's important water uses, an element of risk is inherently present. This risk, in most areas of the Province is acceptable and necessary due to the benefits gained through social and economic development. However, because of the excellent water quality and the value of the uses supported by the water in this pristine condition, these risks are thought not to be acceptable or necessary in certain limited areas of the Province. Application of such designations would not be unilateral, but would reflect policy determined after thorough review and consultation following for example, the Watershed Classification process.

It is felt also, that the designation "High Quality Waters" more clearly reflects the intent of the previous "non-degradation" classification for the upper Grass and Burntwood Rivers (Clean Environment Commission, 1982). Specific areas of the province have not yet been considered for application of the Exceptional Value designation.

2.4 Domestic Consumption Objectives for Fecal Coliform Bacteria

Minor revisions were made to this section in an attempt to more clearly indicate the intended application. It is considered that the objectives as stated are appropriate and that the introduction adequately clarifies the intent. The intent simply, is that "man-induced water quality alterations not cause an unacceptable increased risk to public health or an unacceptable increased treatment cost to the water user or supplier". The objectives are suitable, as a starting point, to assist in determining whether certain discharges or activities are likely to cause such increased risk to health or cost to water purveyors. Hence, for example, if downstream water users utilize a system of water treatment consisting only of simple disinfection, then water quality should not be altered to cause 90% of samples for fecal coliform bacteria to exceed 10 organisms/100 mL. Increased risk to the health of downstream users would result or increased treatment cost would be incurred in order to incorporate another level of drinking water treatment. Further, should downstream water users utilize a sophisticated system of water treatmemt processes designed to recover raw water of extremely poor microbiological quality, upstream discharges of unlimited microbiological quality could theoretically occur without causing increased risk to health or increased water treatment costs. Similar examples could be cited for other domestic consumption parameters.

2.5 The Definition of Toxic Substances and Nutrients with Regard to General Requirements for Water Quality

Major revisions to these definitions are not warranted at the present time. Such general requirements must be stated in broad terms in order to provide protection in areas not adequately covered by the specific numerical water quality objectives. It is recognized that implementation of these general requirements may not be practical in some circumstances and may be controversial in others. However, application of water quality protection guidelines occurs only after consultation processes (e.g., Clean Environment Commission public hearings). It is expected that dialogue between reasonable persons will result in consensus in these areas for which limited scientific knowledge exists.

3.0 Differences Between the U.S. EPA and the CCREM Methods to Derive Criteria for the Protection of Aquatic Life

The U.S. EPA developed a new method for deriving numerical criteria for the protection of aquatic life in 1979. Several modifications were made, then final methods were published in 1985 (U.S. EPA 1985a). The principles of this method were adopted for use in Manitoba (Williamson 1983). The method is summarized below:

a) The method is predicated on the premise that all aquatic species need not be protected in all places at all times. Aquatic ecosystems can tolerate some stress and can recover. A small fraction of organisms therefore will not be afforded protection. This small fraction of sensitive organisms may be replaced through normal ecological succession by other, more tolerant forms, within similar functional groups. The small fraction that does not require protection has been estimated to be 5% of the organisms listed by genera. In some cases, a lower percentile is required when this fifth percentile contains commercially or recreationally important species that would not be protected. Modifications can be implemented to similarly exclude other organisms such as numerical or ecological dominants or other important species. Consequently, some adverse effects are expected. The objectives are intended to avoid unacceptable adverse effects.

b) A minimum data base of acceptable laboratory toxicity information must be utilized. Data must be available for acute and chronic toxicity tests conducted with various aquatic organisms, occupying different taxonomical and ecological functional groups (i.e., various fish, zooplankton, benthic invertebrates, etc.).

c) The fifth percentile of the acute toxicity data base, arranged according to genera, is determined using U.S. EPA's (1985a) modified cumulative probability analyses. The resulting value, called the Final Acute Value, represents a concentration at which 50% of the test species in 5% of the genera would be lethally affected within a short period of time (usually 96 hours).

d) An Acute-Chronic Ratio is determined from the available data. Data useful for this analyses include acute and chronic tests on aquatic organisms conducted by the same researcher using the same test water.

e) The Final Acute Value is divided by the Acute-Chronic Ratio. The resulting concentration, defined as the Final Chronic Value, is an estimation of the concentration of a material that would not produce unacceptable adverse effects in all but the fifth percentile of a group of diverse aquatic genera during long-term exposure. The Final Chronic Value could also be determined using similar methods described for the calculation of the Final Acute Value. However, usually not enough chronic data are available; a consequence of the technical difficulty and expense of generating such data.

f) The Final Chronic Value is associated with water quality variables, such as hardness, if the toxicity is affected by changes in that variable.

g) A Final Residue Value is calculated by dividing, for example, permissable edible tissue concentrations necessary to protect human health by a Bioconcentration Factor. The Final Chronic Value may be lowered to the Final Residue Value, for example, to account for the bioconcentration of pollutants (e.g., mercury), such that either aquatic life or their uses would be unacceptably affected. Adjustments may also be required to account for other effects, for example, on aquatic plants, that may be biologically important.

The method adopted by the CCREM (CCREM 1987) for developing similar guidelines for the protection of aquatic life within Canada differs in a number of substantial practical and philosophical ways. The CCREM method is intended to protect all forms of aquatic life and all life stages during indefinite exposure. Toxicological data that reflects no negative effects are relied upon by the CCREM method. Exceptions are identified to allow for circumstances of insufficient information or the localized occurrence of a certain organism. This can be contrasted with the U.S. EPA method that attempts to prevent unacceptable effects of a toxic material upon an aquatic ecosystem, rather than all effects. The basis of the U.S. EPA method is founded in ecological theory that suggests that most communities can withstand a certain degree of stress and can readjust, without any apparent unacceptable consequences upon the ecological community.

Implicit with the different methods is the expectation therefore, that the guidelines derived by the CCREM method should be more restrictive than the criteria developed using the U.S. EPA method. This expectation generally holds, although there are a number of notable exceptions.

While the Manitoba Department of Environment and Workplace Safety and Health accepts without question that the ultimate goal of environmental protection should be similar to that of the CCREM, this goal does not appear reasonable or practical in many common circumstances. The goal is not readily achievable given society's continued increase in population, the fact that most major urban centers have located out of necessity in close proximity to water, and our attempt to seek a balanced social advancement through continued industrial expansion. That is, it must be recognized that all man's activities however subtle, nevertheless affect the surrounding environment to some degree. It therefore follows that it becomes an impossible task at the outset to attempt to provide protection to all organisms during all lifestages during indefinite exposure to materials resulting from man's activities. Hence, in order for the Manitoba Surface Water Quality Objectives to continue to be a practical everyday tool to assist with water quality management activities, they must be founded on a realization of these limitations.

The goal of the Manitoba Surface Water Quality Objectives is to offer a blend of protection such that in heavily populated areas ecosystem function is maintained and direct water use by humans is not unacceptably impaired. However, in the more pristine areas of Manitoba, unequivocal protection will be afforded all organisms at all times and in all places. The latter goals are articulated in the High Quality and Exceptional Value designations. Modifications were made to the High Quality Designation to ensure that this goal was clearly stated.

During the review of the most recent drafts, the Clean Environment Commission was clearly opposed philosophically to the above position. The Clean Environment Commission expressed the opinion that it was difficult to accept the principle that all aquatic life were not going to be offered protection. Given the fact that the Manitoba Surface Water Quality Objectives were merely objectives and not enforceable standards, the Commission expressed the view that the starting point for further modification in light of their "objective" status should be one of providing complete protection. The Commission further argued that Manitoba should adopt many of the numerical values and philosophy of the CCREM in order to achieve the goal of a uniform national approach to water quality protection.

The Manitoba Department of Environment and Workplace Safety and Health agrees completely with the high goals expressed by the Clean Environment Commission. However, it remains an inescapable fact that offering full protection to aquatic life is not possible given the realization that merely by our co-existence with the environment, some change is inevitable. The practical goal is to ensure that this change does not exceed a certain unacceptable minimum level.

This issue remains largely unresolved but it can certainly benefit from further honest and wide ranging discussion in the future. The Manitoba Department of Environment and Workplace Safety and Health felt that despite the difference of opinion, it was desirable to proceed along the present course, at the present time. It should be noted that proceeding in this directon at the present time does not preclude making modifications in the future based either

upon scientific evidence or opinion or based upon an expression of both public and government support for an additional safety margin with a full realization of the inherent social and economic costs.

4.0 Revisions to Specific Numerical Objectives, Class 2: Aquatic Life and Wildlife

Revisions are warranted for the parameters un-ionized ammonia, arsenic, cadmium, chlorine, chromium, copper, cyanide, lead and mercury within Class 2: Aquatic Life and Wildlife. These revisions reflect new scientific knowledge recently published by the United States Environmental Protection Agency (U.S. EPA). The U.S. EPA issued notice in the Federal Register on Monday, July 29, 1985 advising that new criteria documents were available for these parameters. The U.S. EPA further advised that these new criteria superceded previous U.S. EPA criteria for these parameters (U.S. EPA 1976; U.S. EPA, 1980 a-f). The Manitoba Surface Water Quality Objectives (Williamson, 1983) for these parameters had been adopted from the superceded U.S. EPA criteria documents.

Additionally, the form of the criteria for arsenic, cadmium, chromium, copper, and lead has been altered from total recoverable to acid-soluble species. Acid-soluble is defined as that concentration that passes through a 0.45 μm membrane filter after the sample is acidified to a pH of 1.5 to 2.0 with nitric acid. The U.S. EPA advise that the total recoverable measurement is probably too rigorous in some situations. The following passages have been excerpted from the criteria document for arsenic (U.S. EPA 1985c), with minor editorial changes for this context, but is equally applicable to cadmium, chromium, copper, and lead (and probably to other objectives for similar materials presently expressed as total or total recoverable forms):

"Acid-soluble is probably the best measurement at the present for the following reasons.

1. This measurement is compatible with nearly all available data concerning toxicity and bioaccumulation of (these materials) by

aquatic organisms. Very few test results were rejected just because it was likely that they would have been substantially different if they had been reported in terms of acid-soluble.

2. On samples of ambient water, measurement of acid-soluble materials should measure all forms that are toxic to aquatic life or can be readily converted to toxic forms under natural conditions. In addition, this measurement should not measure several forms, such as those that are occluded in minerals, clays, and sand or are strongly sorbed to particulate matter, that are not likely to become toxic under natural conditions. Although this measurement (and many others) will measure soluble, complexed forms of these materials, such as the EDTA complexes, that probably have low toxicities to aquatic life, concentrations of these forms probably are negligible in most ambient water.
3. Although water quality criteria apply to ambient water, the measurement used to express criteria is likely to be used to measure such materials in aqueous effluents. Measurement of acid-soluble materials should be applicable to effluents because it will measure precipitates, such as carbonate and hydroxide precipitates, that might exist in an effluent and dissolve when the effluent is diluted with receiving water. If desired, dilution of effluent with receiving water before measurement of acid-soluble materials might be used to determine whether the receiving water can decrease the concentration of acid-soluble materials because of sorption.
4. The acid-soluble measurement should be useful for most metals, thus minimizing the number of samples and procedures that are necessary.
5. The acid-soluble measurement does not require filtration at the time of collection, as does the dissolved measurement.
6. The only treatment required at the time of collection is preservation by acidification to pH = 1.5 to 2.0, similar to that required for the total recoverable measurement.
7. Durations of 10 minutes to 24 hours between acidification and filtration probably will not affect the result substantially.

8. The carbonate system has a much higher buffer capacity from pH = 1.5 to 2.0 than it does from pH = 4 to 9 (Weber and Stumm, 1963).
9. Differences in pH within the range of 1.5 to 2.0 probably will not affect the result substantially.
10. The acid-soluble measurement does not require a digestion step, as does the total recoverable measurement.

The U.S. EPA (Martin et al. 1986) evaluated acid-soluble methods for determining arsenic, aluminum, cadmium, chromium, copper, lead, mercury, nickel, silver and zinc. It was found that mercury and silver were not suitable for analyses by acid-soluble methods. Howevere, tentative methods were proposed for the other elements. The U.S. EPA (Martin et al. 1986) recommended that further interlaboratory evaluation was necessary before these methods could be accepted for widespread use.

Considerable uncertainty surrounds the choice of the analytical method for expressing objectives for trace metals. Most agencies in Canada, including the Canadian Council of Resource and Environment Ministers (CCREM 1987), have opted to express such objectives as "total" metal forms . Most historical water quality data for trace metals have been analyzed using total methods. Further, it was thought that some protection would be offered aquatic organisms from the possibility of sediment-bound metals being remobilized and transported elsewhere within the aquatic system to later cause toxic effects.

However, Manitoba's historical data base for trace metals has largely been developed utilizing the acid-extractable method of analyses. This procedure differs from the proposed acid-soluble method only with respect to absence of the filtration step (settling of particulate matter is allowed to occur), accurate control over the pH of the extraction (although a random check has indicated that the proposed U.S. EPA (Martin et al. 1986) pH end-point is being achieved) and the length of time that extraction is allowed to proceed. This method was retained for use in Manitoba despite the general trend

elsewhere to move to "total" analytical methods for metals. It was thought that this method more closely reflected the actual amount of metals that were available to biological organisms; a philosophy that is presently being supported by the U.S. EPA.

Consequently, surface water quality objectives for these trace metals will be expressed as acid-soluble as recommended by the U.S. EPA (1985c, d, f, g, i, j) with the exception of mercury and silver. Surface water quality objectives for mercury and silver will be expressed as total. Analyses for these metals, with the exception of mercury and silver, will continue to be conducted by the acid-extractable method until final acid-soluble methods are available from the U.S. EPA and are evaluated for applicability within Manitoba.

4.1 Ammonia, Un-ionized as NH_3

Existing Objective: 0.02 mg/L un-ionized ammonia as NH_3.

Reference: U.S. EPA (1976).

Revised Objective: Variable, ranging from 0.0184 to 0.050 mg/L un-ionized ammonia as NH_3.

pH	0°C	5°C	10°C	15°C	20°C	25°C	30°C
6.50	0.0184	0.0184	0.0184	0.0184	0.0184	0.0184	0.0184
6.75	0.0184	0.0184	0.0184	0.0184	0.0184	0.0184	0.0184
7.00	0.0184	0.0184	0.0184	0.0184	0.0184	0.0184	0.0184
7.25	0.0184	0.0184	0.0184	0.0184	0.0184	0.0184	0.0184
7.50	0.0184	0.0184	0.0184	0.0186	0.026	0.026	0.026
7.75	0.0184	0.0184	0.022	0.031	0.043	0.043	0.043
8.00	0.0184	0.0184	0.025	0.035	0.050	0.050	0.050
8.25	0.0184	0.0184	0.025	0.035	0.050	0.050	0.050
8.50	0.0184	0.0184	0.025	0.035	0.050	0.050	0.050
8.75	0.0184	0.0184	0.025	0.035	0.050	0.050	0.050
9.00	0.0184	0.0184	0.025	0.035	0.050	0.050	0.050

Objectives can be interpolated for other ambient pH and temperature characteristics within the respective ranges of 6.50 to 9.00 and 0°C to 30°C with the following equations:

$$\text{Ammonia Objective} = 0.80/FT/FpH/Ratio^{a}$$

Where $FT = 1$, when $T \geq 20°C$;

$FT = 10^{0.03(20-T)}$, when $T < 20°C$;

$FpH = 1$, when $8 \leq pH \leq 9$;

$$FpH = \frac{1 + 10^{7.4-pH}}{1.25}, \text{ when } 6.5 \leq pH \leq 8;$$

$Ratio = 16$, when $7.7 \leq pH \leq 9$;

$$Ratio = \frac{24 \cdot 10^{7.7-pH}}{1+10^{7.4-pH}}, \text{ when } 6.5 \leq pH \leq 7.7.$$

a. Except when FT • FpH • Ratio > 43.48; then 43.48 should be used as the denominator (this is a modification necessary to place a lower limit of 0.0184 mg/L on the objective rather than the original lower limit of 0.0007 mg/L un-ionized ammonia).

Reference: U.S. EPA (1985b), with modifications.

Rationale

The following was summarized from U.S. EPA (1985b):

Un-ionized ammonia exists in equilibrium in aqueous solutions with the ammonium ion and the hydroxide ion. The equilibrium equation can be expressed as follows:

$$NH_3(g) + nH_2O(l) \rightleftarrows NH_3 \cdot nH_2O(aq) \rightleftarrows NH_4^+ + OH^- + (n-1)\ H_2O\ (l)$$

The dissolved un-ionized ammonia, expressed as NH_3, is present as a gas. The ionized form is expressed as NH_4^+. Total ammonia is the sum of NH_3 and NH_4^+.

The toxicity of aqueous ammonia solutions to aquatic organisms has been attributed primarily to the un-ionized form, NH_3. Since analytical methods are not available for readily measuring the un-ionized form, equilibrium relationships are used to calculate the NH_3 form from a measurement of total ammonia ($NH_3 + NH_4^+$). This equilibrium is affected principally by temperature and pH. For example, at 30°C and at a pH of 10.0, nearly 90% of the total ammonia is present in the un-ionized form. Conversely, at 0°C and at a pH of 6.0, approximately 0.008% of the total ammonia is present in the un-ionized form (NH_3) (Table 3). The percent un-ionized ammonia can be calculated using the following formula (Emerson et al. 1975):

$$f = \frac{1}{10(pKa - pH) + 1} \times 100$$

Where:

f = the percent of the total ammonia in the un-ionized state,

$$pKa \text{ (dissociation constant for ammonia)} = 0.09018 + \frac{2729.92}{(273.16 + °C)}$$

°C = temperature in degrees Celsius

Un-ionized ammonia was reported to be acutely toxic at concentrations ranging from 0.53 to 22.8 mg/L for 19 invertebrate species from 14 families and 16 genera. Acute toxicity ranged from 0.083 to 4.60 mg/L for 29 fish species from 9 families and 18 genera. Chronic toxicity ranged from 0.0017 to 0.612 mg/L for 9 freshwater fish species from 5 families and 7 genera.

The several most acutely sensitive fish species are members of the Salmonidae, Cyprinidae, Percidae and Catostomidae families. The species most chronically sensitive to un-ionized ammonia include representatives from Salmonidae, Cyprinidae, Ictaluridae, Centrarchidae and Catostomidae families. The U.S. EPA (1985b) advised that differences in sensitivities between "warm" and "cold" water fish species (and probably Manitoba's "cool" water species) are minor and do not warrant separate criteria. Should discrimination be desirable,

then specific criteria should be developed accounting for the sensitivities of the species inhabiting the particular site of interest.

Acute toxic responses of fish to un-ionized ammonia includes loss of equilibrium, hyperexcitability, increased breathing, cardiac output and oxygen uptake, convulsions, coma and death. Chronic responses include a reduction in hatching success, reduction in growth rate and morphological development and pathological changes in tissues of gills, livers and kidneys. The toxicity of un-ionized ammonia to fish is modified by several factors. These include factors that affect the equilibrium of ammonia, thus affect the concentration of un-ionized ammonia. Other factors decrease the actual toxicity of ammonia. These include dissolved oxygen concentrations, temperature, pH, previous acclimation to ammonia, fluctuating or intermittent exposures, carbon dioxide concentrations, salinity and the presence of other toxicants. Sufficient data exist to enable the development of a regression equation for the acute toxicity of un-ionized ammonia on two of these factors: pH and temperature. These relationships are stated above in the revised objective section. All acute toxicity data were transformed to equivalent concentrations at a standard pH of 8.0 and a standard temperature of 20°C using these relationships. A Final Acute Value of 0.70 mg/L was calculated from these standardized values. For derivation of the Final Chronic Value, the Final Acute Value was adjusted upward to 0.80 mg/L to account for bias that resulted from including data for the mountain whitefish and rainbow trout that were derived from extremely sensitive life stages. Data on the applicability of these relationships developed with acute toxicity data to chronic exposure levels was scarse; however, U.S. EPA felt that not applying these relationships was clearly less desirable. Consequently, these relationships have been used to calculate Final Chronic Values at various pH and temperature values.

Acute-Chronic Ratios were available for ten species and ranged from 3 to 43. Five of these were selected for species that corresponded most closely with the fifth percentile (i.e., had acute

sensitivities nearest 0.80 mg/L). The ratios selected were 10 (channel catfish), 12 (bluegill), 14 (rainbow trout), 20 (fathead minnow), and 30 (white sucker). The geometric mean of these ratios was 16. This ratio is probably affected by changes in pH. Although data were limited, the U.S. EPA felt that this ratio may increase to values greater than 20 at lower pH's.

Modification For Application Within Manitoba

Two modifications of the U.S. EPA (1985b) un-ionized ammonia criteria are desirable in order to better apply to Manitoba's situation. Firstly, U.S. EPA (1985b) recommended two ranges of criteria, one for the protection of waters containing salmonids and other sensitive cold water species, the second for the protection of waters for which such species are absent. The criteria for the former ranges from 0.0007 to 0.035 mg/L un-ionized ammonia and for the latter, ranges from 0.0007 to 0.050 mg/L un-ionized ammonia. The difference was caused by the placement of a temperature "cap" of 15°C for the former group, whereas a "cap" of 20°C was used for the latter group. The U.S. EPA (1985b) advised that this was necessary since toxicity tests were not conducted with salmonids at temperatures significantly greater than 15°C and therefore, little confidence could be placed in the extrapolation to higher temperatures. The U.S. EPA (1985b) further advised that temperatures significantly greater than 15°C would itself be stressful to these species of organisms, thus would confound the interpretation of toxicity tests conducted at such temperatures. However, it is believed that the one broader range of criteria, 0.0007 to 0.050 mg/L un-ionized ammonia, would afford reasonable protection, even to Manitoba's predominately cool water and cold water assemblage of organisms. This assumption is predicated on the fact that temperature preferences would limit the distribution or range of these species within Manitoba to waters that generally remain below 15°C. Therefore, it becomes redundant to administratively adopt a range of criteria to protect aquatic organisms from the unacceptable

adverse effect of un-ionized ammonia, when natural temperature would preclude these sensitive cold water species from inhabiting waters with such ambient temperature characteristics.

Secondly, as previously mentioned, the U.S. EPA (1985b) derived the criteria with the application of mathematical regression equations developed for acute toxicity data with pH and temperature ameliorative effects. The U.S. EPA's best scientific judgement indicated that these relationships would probably also apply at lower chronic toxicity ranges, even though the chronic toxicity data base was limited and did not fully support such an extrapolation. The available chronic data base was reviewed, and it was thought appropriate to place a lower limit on the range of criteria at least until the applicability of these relationships to extremely low temperature and pH ambient conditions is further substantiated.

The limited chronic toxicity data base was objectively assessed using methods congruent with the U.S. EPA (1985a) criteria development approach. The available chronic toxicity data base (U.S. EPA 1985b) were listed in order of descending values, ranks were assigned and probabilities were calculated (Table 1). The data were not averaged by genera as would normally be done for this type of analyses, since our purpose was merely to identify the lower bounds of the data base. Further, two extremely sensitive species not resident in Manitoba were eliminated from this analysis, namely the pink salmon (Oncorhynchus gorbuscha) and the atlantic salmon (Salmo salar). Cumulative probability analyses was used (U.S. EPA 1985a) to determine the fifth percentile (Table 2). These calculations resulted in the identification of 0.0184 mg/L un-ionized ammonia corresponding to the fifth percentile. It is therefore believed that 0.0184 mg/L un-ionized ammonia is an appropriate limit to be placed on the U.S. EPA (1985b) criteria for use within Manitoba at least until further research substantiates the need to extend the lower range to 0.0007 mg/L, as recommended by the U.S. EPA.

It should be noted that the cumulative probability analyses was influenced by the elimination of data for the pink salmon (Oncorhynchus gorbuscha) and the atlantic salmon (Salmo salar). Had these species been included, the identified lower limit of 0.0184 mg/L would have been substantially reduced. The obvious danger of eliminating these species from this analyses, given the limited available chronic toxicity data base, is that some of Manitoba's many untested species may have similar sensitivities to un-ionized ammonia.

In summary, it is felt that the U.S. EPA (1985a) un-ionized ammonia criteria represent the best scientific information available, that such criteria are generally applicable to Manitoba, but that a lower limit of 0.0184 mg/L be placed on the criteria at least until extrapolation to the U.S. EPA's recommended lower bound of 0.0007 mg/L can be further substantiated by scientific experiment.

Table 1: Available un-ionized ammonia chronic toxicity data base, listed in descending order of magnitude.

Species	Chronic Value	Rank	Probability (Rank)/(n+1)
Cladoceran *Daphnia magna*	1.2 mg/L	22	0.95652
Cladoceran *Daphnia magna*	0.63 mg/L	21	0.91304
Smallmouth bass *Micropterus dolomieui*	0.612 mg/L	20	0.86957
Smallmouth bass *Micropterus dolomieui*	0.599 mg/L	19	0.82609
Cladoceran *Daphnia magna*	0.527 mg/L	18	0.78261
Green Sunfish *Lepomis cyanellus*	0.33 mg/L	17	0.73913
Cladoceran *Ceriodaphnia acanthina*	0.304 mg/L	16	0.69565
Channel catfish *Ictalurus punctatus*	0.283 mg/L	15	0.65217
Channel catfish *Ictalurus punctatus*	<0.25 mg/L	14	0.60867
Fathead minnow *Pimephales promelas*	0.22 mg/L	13	0.56522
Channel catfish *Ictalurus punctatus*	0.18 mg/L	12	0.52174
Smallmouth bass *Micropterus dolomieui*	0.148 mg/L	11	0.47826
Fathead minnow *Pimephales promelas*	0.13 mg/L	10	0.43478
Fathead minnow *Pimephales promelas*	0.13 mg/L	9	0.39130
Channel catfish *Ictalurus punctatus*	0.103 mg/L	8	0.34783

Table 1: (Continued)

Species	Chronic Value	Rank	Probability (Rank) (n+1)
Bluegill *Lepomis macrochirus*	0.0926 mg/L	7	0.30435
Rainbow trout *Salmo gairdneri*	0.085 mg/L	6	0.26087
Rainbow trout *Salmo gairdneri*	<0.06 mg/L	5	0.21739
White sucker *Catostomas commersoni*	0.058 mg/L	4	0.17391
Smallmouth bass *Micropterus dolomieui*	0.0437 mg/L	3	0.13044
Rainbow trout *Salmo gairdneri*	0.0311 mg/L	2	0.08696
Rainbow trout *Salmo gairdneri*	0.016 mg/L	1	0.04348
Atlantic Salmon *Salmo salar*	0.01 mg/L	excluded	
Pink Salmon *Oncorhynchus gorbuscha*	0.0031 mg/L	excluded	
Pink Salmon *Oncorhynchus gorbuscha*	0.0017 mg/L	excluded	
Pink Salmon *Oncorhynchus gorbuscha*	0.0017 mg/L	excluded	

able 2: Identification of the 0.05 fraction of the un-ionized ammonia chronic toxicity data base using cumulative probability analyses.

ank	Chronic Value	ln Chronic Value	(ln Chronic Value)^2	Probability	Probability
4	0.058	- 2.84731	8.10712	0.17391	0.41703
3	0.0437	- 3.13041	9.79947	0.13044	0.36117
2	0.0311	- 3.47055	12.04472	0.08696	0.29489
1	0.016	- 4.13517	17.09963	0.04348	0.20852
		-13.58344	47.05093	0.43479	1.28160

$$^2 = \frac{\Sigma [(\ln CV)^2] - [(\Sigma (\ln CV))^2/4]}{\Sigma(P) - [(\Sigma (\sqrt{P}))^2/4]}$$

$$= \frac{47.05093 - (-13.58344)^2/4}{0.43479 - (\sqrt{1.28160})^2/4}$$

$$= \frac{0.923537}{0.0241654}$$

$$= 38.217342$$

$$= 6.18202$$

$$= [\Sigma (\ln CV) - s (\Sigma (\sqrt{P}))]/4$$

$$= [-13.58344 - 6.18202(\sqrt{1.28160})]/4$$

$$= -5.376577$$

$$= s (\sqrt{0.05}) + L$$

$$= (6.18202) (\sqrt{0.05}) - 5.376577$$

$$= -3.994235$$

hronic Value = $e^{-3.994235}$

= 0.0184 mg/L un-ionized ammonia as NH_3

Table 3: Percent un-ionized ammonia in total ammonia solution for temperature and pH ranges of 0 to 30°C and 6 to 10 pH units, respectively (Emerson et al. 1975).

Temp.	pH (pH units)								
(°C)	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
0	.00827	.0261	.0826	.261	.820	2.55	7.64	20.7	45.3
1	.00899	.0284	.0898	.284	.891	2.77	8.25	22.1	47.3
2	.00977	.0309	.0977	.308	.968	3.00	8.90	23.6	49.4
3	.0106	.0336	.106	.335	1.05	3.25	9.60	25.1	51.5
4	.0115	.0364	.115	.363	1.14	3.52	10.3	26.7	53.5
5	.0125	.0395	.125	.394	1.23	3.80	11.1	28.3	55.6
6	.0136	.0429	.135	.427	1.34	4.11	11.9	30.0	57.6
7	.0147	.0464	.147	.462	1.45	4.44	12.8	31.7	59.5
8	.0159	.0503	.159	.501	1.57	4.79	13.7	33.5	61.4
9	.0172	.0544	.172	.542	1.69	5.16	14.7	35.3	63.3
10	.0186	.0589	.186	.586	1.83	5.56	15.7	37.1	65.1
11	.0201	.0637	.201	.633	1.97	5.99	16.8	38.9	66.8
12	.0218	.0688	.217	.684	2.13	6.44	17.9	40.8	68.5
13	.0235	.0743	.235	.738	2.30	6.92	19.0	42.6	70.2
14	.0254	.0802	.253	.796	2.48	7.43	20.2	44.5	71.7
15	.0274	.0865	.273	.859	2.67	7.97	21.5	46.4	73.3
16	.0295	.0933	.294	.925	2.87	8.54	22.8	48.3	74.7
17	.0318	.101	.317	.996	3.08	9.14	24.1	50.2	76.1
18	.0343	.108	.342	1.07	3.31	9.78	25.5	52.0	77.4
19	.0369	.117	.368	1.15	3.56	10.5	27.0	53.9	78.7
20	.0397	.125	.396	1.24	3.82	11.2	28.4	55.7	79.9
21	.0427	.135	.425	1.33	4.10	11.9	29.9	57.5	81.0
22	.0459	.145	.457	1.43	4.39	12.7	31.5	59.2	82.1
23	.0493	.156	.491	1.54	4.70	13.5	33.0	60.9	83.2
24	.0530	.167	.527	1.65	5.03	14.4	34.6	62.6	84.1
25	.0569	.180	.566	1.77	5.38	15.3	36.3	64.3	85.1
26	.0610	.193	.607	1.89	5.75	16.2	37.9	65.9	85.9
27	.0654	.207	.651	2.03	6.15	17.2	39.6	67.4	86.8
28	.0701	.221	.697	2.17	6.56	18.2	41.2	68.9	87.5
29	.0752	.237	.747	2.32	7.00	19.2	42.9	70.4	88.3
30	.0805	.254	.799	2.48	7.46	20.3	44.6	71.8	89.0

4.2 Arsenic

Existing Objective: 0.05 mg/L, total arsenic.

Reference: Environment Canada (1979).

Revised Objective: 190 µg/L, acid-soluble arsenic.

Reference: U.S. EPA (1985c), with modifications.

Rationale: The following was summarized from U.S. EPA (1985c).

The chemistry of arsenic in natural waters is complex and is affected by chemical, biochemical and geochemical reactions. Such reactions alter the concentration, oxidation state, and the form of arsenic in water. Four arsenic species were reported to occur in natural water. These included inorganic trivalent and pentavalent, methanearsonic acid, and dimethylarsinic acid. Both the chemical and toxicological properties of these forms differ, hence, they must be treated as separate compounds with regard to criteria development.

Trivalent inorganic arsenic acute toxicity data were available for sixteen genera of which nine were invertebrates and six were fish species. Acute toxicity ranged from 812 µg/L for a cladoceran to 97,000 µg/L for the chironomid Tanytarsus dissimilis. Fish species were intermediate within this range in terms of acute toxicity. Toxicity data for trivalent inorganic arsenic were found to be unrelated to water hardness, at least for the bluegill. The Final Acute Value was 718.2 µg/L.

Pentavalent inorganic arsenic acute toxicity data ranged from 850 µg/L for a cladoceran to 49,000 µg/L for the mosquito fish. Acute toxicity data for monosodium methanearsonate ranged from 1921 µg/L for the bluegill to 1,403,000 µg/L for the channel catfish. Insufficient data were available for pentavalent arsenic and monosodium methanearsonate in order to derive criteria.

Chronic toxicity data with trivalent inorganic arsenic were available for three genera, namely a cladoceran (Daphnia magna), the fathead minnow (Pimephales promelas) and the flagfish (Jordanella floridae). These data were 914.1, 3026 and 2962 µg/L respectively.

Acute-Chronic Ratios were available for three species. The

geometric mean of these ratios was 3.803. Division of the Final Acute Value by the Acute-Chronic Ratio resulted in a Final Chronic Value of 188.9 µg/L.

Inorganic trivalent arsenic was reported to be toxic to aquatic plants at concentrations ranging from 2320 to 59,000 µg/L. Toxicity of inorganic pentavalent arsenic to plants ranged from 48 to 202,000 µg/L. Bioconcentration factors ranged to 17 with a snail exposed to inorganic arsenic.

Modification for Application Within Manitoba

The U.S. EPA (1985c) recommended the derived Final Chronic Value of 188.9 µg/L (rounded to 190 µg/L) acid-soluble trivalent inorganic arsenic for their "criterion continuous concentration". With the exception of exceedences of short duration and small magnitude, this criterion represented a concentration that would provide reasonable protection to aquatic life following long-term exposure. The U.S. EPA (1985c) also advised, as previously briefly discussed, that the four forms of arsenic common in natural waters should be handled separately during criteria development procedures. This was necessary because the various forms of arsenic have unique toxicological properties and these properties could not be considered additive. The U.S. EPA (1985c) further advised that insufficient data were available to derive criteria for forms other than trivalent inorganic arsenic.

Notwithstanding the insufficient data base, it would appear that aquatic life may not be afforded adequate protection from the unacceptable adverse effects of all forms of arsenic with an objective only for trivalent inorganic arsenic. Hence, within Manitoba, this objective will be expressed as acid-soluble arsenic, thus applying to all acid-soluble forms of arsenic.

Review of the toxicological data for other forms of arsenic indicate that this approach likely would not be unreasonably under protective. Refinement of this objective will occur once further scientific information is generated with regard to the toxicity of other forms of arsenic to aquatic life.

4.3 Cadmium

Existing Objective: $e^{(1.05[\ln(\text{hardness})]-8.53)}$, total recoverable cadmium, where hardness is expressed in mg/L as $CaCO_3$ and the resultant objective is expressed in µg/L.

(e.g.) 50 mg/L $CaCO_3 \equiv$ 0.012 µg/L
100 mg/L $CaCO_3 \equiv$ 0.025 µg/L
200 mg/L $CaCO_3 \equiv$ 0.051 µg/L

Reference: U.S. EPA (1980a).

Revised Objective: $e^{(0.7852[\ln(\text{hardness})]-3.490)}$, acid-soluble cadmium, where hardness is expressed in mg/L as $CaCO_3$ and the resultant objective is expressed in µg/L.

(e.g.) 50 mg/L $CaCO_3 \equiv$ 0.66 µg/L
100 mg/L $CaCO_3 \equiv$ 1.1 µg/L
200 mg/L $CaCO_3 \equiv$ 2.0 µg/L

Reference: U.S. EPA (1985d).

Rationale: The following was summarized from U.S. EPA (1985d):

Acute toxicity data were available for 44 genera. Such data ranged from 1.0 µg/L for rainbow trout to 28,000 µg/L for a mayfly. Hardness or ions associated with hardness was found to be antagonistic with the acute toxicity of cadmium for five species.

Chronic toxicity data were available for 16 species in 13 genera. These data included 4 invertebrates and 12 fishes. Chronic toxicity ranged from 0.15 to 156 µg/L for Daphnia magna and the atlantic salmon, respectively. Acute-Chronic Ratios ranged from 0.9021 for the chinook salmon to 433.8 for the flagfish. Hardness was also found to be antagonistically related with the chronic toxicity of two species. Covariance analyses of the natural logarithm of the chronic values with the natural logarithm of the hardness concentration resulted in slopes of 0.77 and 0.81 for Daphnia magna and the fathead minnow, respectively. The pooled slope was 0.7852.

The pooled slope of 0.7852 was used to convert all available chronic values for individual tested species to equivalent values at a common hardness of 50 mg/L $CaCO_3$. These standardized values were then used to calculate geometric mean genus chronic values, and were ranked in descending order of sensitivity. Cumulative probability analyses was used

to determine the fifth percentile in accordance with the methods previously summarized from U.S. EPA (1985a). The U.S. EPA however allowed n to equal 44 since five of the six most acutely sensitive genera to cadmium were included in the analyses, rather than n to equal 13 (this resulted in a less conservative Final Chronic Value). The Final Chronic Value was calculated to be 0.6582 µg/L at a hardness of 50 mg/L $CaCO_3$. The regression equation $e^{(0.7852[\ln(\text{hardness})]-3.949)}$ can be used to determine chronic values at other hardness concentrations.

The U.S. EPA (1985d) advised that two cladoceran species, D. magna and Moina macrocopa may not be afforded adequate protection with the use of these derived criteria.

Bioconcentration factors for cadmium ranged from 3 to 2213, with a geometric mean of 648.6 for brook trout muscle tissue and mosquito fish whole body tissue, respectively. The available information indicated that the Final Chronic Value described above should provide adequate protection to humans from the accumulation of excessive quantities of cadmium following the ingestion of contaminated edible food fish.

Modifications for Application Within Manitoba

Modification of the U.S. EPA derived criteria is not necessary for application within Manitoba as a surface water quality objective.

4.4 Chlorine

Existing Objective: 0.002 mg/L, total residual chlorine, for the protection of cold and cool water aquatic life and wildlife;

0.01 mg/L, total residual chlorine, for the protection of cool water aquatic life and wildlife.

Reference: U.S. EPA (1976).

Revised Objective: 11 µg/L, total residual chlorine.

Reference: U.S. EPA (1985e).

Rationale: The following was summarized from U.S. EPA (1985e):

Chlorine is an effective disinfectant used commonly within water and waste treatment, industrial and food production industries. When chlorine is discharged to freshwater, two free chlorine forms are usually

present, namely hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). If ammonia is present in the receiving water, two combined chlorine forms may result, namely monochloramine and dichloramine. All four forms are toxic to aquatic life. Expression of the criteria as total residual is intended to account for both the two free chlorine forms as well as the two combined chlorine forms.

Acceptable acute toxicity results with total residual chlorine were available for 33 freshwater species. These included 21 fishes and 12 invertebrates. Many of the tested fish species are recreational and commercially important inhabitants of Manitoba's waters. These include rainbow trout, brook trout, white sucker, channel catfish, yellow perch and walleye. Acute toxicity ranged from 27.66 µg/L with the cladoceran Daphnia magna to 710 µg/L for the three spine stickleback (Gasterosteus aculeatus).

Rainbow trout were more sensitive to total residual chlorine than walleye. Species mean acute values for the rainbow trout and walleye were 61.92 and 127.3 µg/L, respectively.

Many water quality factors were observed to influence the acute toxicity of total residual chlorine. However, inconsistent results precluded the development of mathematical relationships between such factors and acute toxicity. The U.S. EPA noted that acute lethality occurred relatively rapidly (i.e., within the first 12 hours of exposure) and that at least with the coho salmon, was only three times higher than that concentration which resulted in no mortalities. A Final Acute Value was calculated to be 38.32 µg/L.

The chronic toxicity data base was rather limited. Acceptable chronic tests were available for four species, only one of which was a fish. Chronic values ranged from less than 3.4 µg/L for the amphipod (Gammarus pseudolimnaeus) to 26.23 µg/L for the fathead minnow (Pimephales promelas).

An Acute-Chronic Ratio of 3.345 was calculated. Division of the Final Acute Value by this Acute-Chronic Ratio resulted in a Final Chronic Value of 11.46 µg/L (rounded to 11 µg/L).

It was reported that correlation was quite good between laboratory derived acute toxicity sensitivity ranking with results from field studies. Field studies conducted at various locations with different total residual chlorine concentrations indicated that as chlorine concentration increased, the fish species disappeared in general order of their laboratory ranked acute sensitivities.

Modification for Application Within Manitoba

It is felt that modifications are not necessary in order to apply the U.S. EPA derived criteria for total residual chlorine within Manitoba as a water quality objective.

4.5 Chromium

Existing Objective: 0.29 µg/L, total recoverable hexavalent chromium.

Reference: U.S. EPA (1980b).

Revised Objective: 11 µg/L, acid-soluble hexavalent chromium;

$e^{(0.8190[\ln(\text{hardness})]+1.561)}$, acid soluble trivalent chromium, where hardness is expressed as $CaCO_3$ in mg/L and the resultant objective is expressed in µg/L.

(e.g.) 50 mg/L $CaCO_3 \equiv$ 120 µg/L
100 mg/L $CaCO_3 \equiv$ 210 µg/L
200 mg/L $CaCO_3 \equiv$ 370 µg/L

Reference: U.S. EPA (1985f).

Rationale: The following was summarized from U.S. EPA (1985f):

Both inorganic trivalent chromium and inorganic hexavalent chromium can exist within natural surface waters. Conversion from one oxidation state to the other can occur under natural conditions. However, the chemical and toxicological properties of the two valence states are significantly different. Thus, criteria were developed separately for both forms.

Acute toxicity results with inorganic hexavalent chromium were available for 27 genera, 18 of which were fish. Acute toxicity ranged

from 28.94 µg/L for a cladoceran to 1,870,000 µg/L for a stonefly. The fish species lie intermediate, with the guppy (Poecilia reticulata) being the most sensitive. The 96 hr LC_{50} for this species was 30,000 µg/L.

The U.S. EPA reported that the acute toxicity of hexavalent chromium is apparently increased by decreases in pH or hardness or both. However, insufficient data exist to define this apparent relationship further. A Final Acute Value of 31.49 µg/L was calculated.

Chronic toxicity results with inorganic hexavalent chromium were available for six genera, three of which were the fish species rainbow trout (Salmo gairdneri), brook trout (Salvelinus fontinalis) and the fathead minnow (Pimephales promelas). Chronic toxicity values ranged from less than 2.5 µg/L for the cladoceran Daphnia magna to 1987 µg/L for the fathead minnow (P. promelas). An Acute-Chronic Ratio of 2.917 was calculated. Division of the Final Acute Value by the Acute-Chronic Ratio resulted in a Final Chronic Value of 10.80 µg/L.

Acute toxicity data with inorganic trivalent chromium were available for 18 genera. Acute toxicity ranged from 2,221 µg/L for the mayfly (Ephemerella subvaria) to 71,060 µg/L for the caddisfly (Hydropshyche betteni). As with inorganic hexavalent chromium, invertebrate genera were both most sensitive and least sensitive with regard to acute toxicity. The eleven fish genera examined were intermediate within this range.

The U.S. EPA reported that the acute toxicity of inorganic trivalent chromium was antagonistic with hardness or hardness related ions such as hydroxide, carbonate, calcium or magnesium. Analyses of covariance was used to determine a pooled slope of 0.8190 for this relationship. All acute values were then converted to an equivalent value at a standard hardness of 50 mg/L $CaCO_3$, then a Final Acute Value of 1968 µg/L was calculated.

Chronic toxicity data with inorganic trivalent chromium were available for the three species: Daphnia magna, rainbow trout (Salmo gairdneri) and the fathead minnow (Pimephales promelas). Chronic toxicity ranged from less than 44 µg/L for one test with the cladoceran D. magna

to 1,025 µg/L for the fathead minnow (P. promelas). Acute-Chronic Ratios ranged from approximately 27 to 1300. Because the Acute-Chronic Ratios spanned over an order of magnitude, they were not useful for deriving a Final Chronic Value from the Final Acute Value. Rather, the chronic value of 68.63 µg/L for the rainbow trout was used as the Final Chronic Value. Hardness was assumed to ameliorate chronic toxicity according to the relationship derived from acute toxicity data. Thus, Final Chronic Values at various hardness characteristics can be calculated with the equation: $e^{(0.8190[\ln(\text{hardness})]+1.561)}$.

Inorganic hexavalent chromium toxicity to aquatic plants ranged from 2 to 7800 µg/L. Inorganic trivalent chromium toxicity to aquatic plants was examined with only two species. A 50% reduction in growth was observed at a concentration of 397 µg/L inorganic trivalent chromium with the green alga Selanastrum capricornutum.

Bioconcentration factors for inorganic hexavalent chromium were less than 3 with the rainbow trout, but ranged to 8500 for plankton. Data were not available regarding the bioaccumulation in aquatic organisms with inorganic trivalent chromium.

Modifications for Application Within Manitoba

The derived U.S. EPA (1985f) criteria for trivalent and hexavalent chromium are appropriate for application within Manitoba as surface water quality objectives without modification.

4.6 Copper

Existing Objective: 5.6 µg/L, total recoverable copper.

Reference: U.S. EPA (1980c).

Revised Objective: $e^{(0.8545[\ln(\text{hardness})]-1.465)}$, acid-soluble copper, where hardness is expressed in mg/L $CaCO_3$ and the resultant objective is expressed in µg/L.

(e.g.) 50 mg/l $CaCO_3 \equiv$ 6.5 µg/L

100 mg/l $CaCO_3 \equiv$ 12 µg/L

200 mg/l $CaCO_3 \equiv$ 21 µg/L

Reference: U.S. EPA (1985g).

Rationale: The following was summarized from U.S. EPA (1985g):

Copper occurs primarily in natural waters as the divalent cupric ion in both free and complexed forms. At low concentrations, copper is a minor nutrient for both plants and animals and at slightly higher concentrations, is toxic to aquatic life. The cupric ion is highly reactive and can form moderate to strong complexes and precipitate with many other natural constituents of water such as carbonate, phosphate, amino acids and humates. This ion is also readily sorbed onto surfaces of suspended solids. Such forms of copper are usually much less toxic than the free cupric ion.

Data generated from acute toxicity tests were available for 41 genera of freshwater animals. Acute toxicity was found to be related antagonistically to hardness and hardness associated carbonate alkalinity. Analyses of covariance was used to define this relationship and resulted in the calculation of a pooled slope of 0.9422. All acute toxicity data were then converted to equivalent values at a hardness of 50 mg/L $CaCO_3$. The northern squawfish (Ptychocheilus oregonensis) and the stonefly (Acroneuria lycorias) were the most sensitive and the least sensitive species, respectively. Ptychocheilus oregonensis is 610 times more sensitive than Acroneuria lycorias. The seven most sensitive genera included both fishes and invertebrates. A Final Acute Value of 18.46 µg/L was calculated.

Data generated from chronic toxicity tests were available for five invertebrate and ten fish species. The chronic values for the fish species ranged from 3.873 µg/L for the brook trout to 60.36 µg/L for the northern pike. The chronic values for the invertebrate species ranged from 6.066 to 29.33 µg/L.

Thirteen Acute-Chronic Ratios were available and ranged from 1.023 to 156.2. The geometric mean of the Acute-Chronic Ratio of the two species nearest the fifth percentile (of ranked genera acute toxicity values) was 2.823. Division of the Final Acute Value with this Acute-Chronic Ratio resulted in a Final Chronic Value of 6.539 µg/L at a corresponding water hardness of 50 mg/L $CaCO_3$. The regression equation derived for acute toxicity with hardness was assumed to apply to chronic values. Thus, the equation $e^{(0.8545[\ln(\text{hardness})]-1.465)}$ can be used to derive chronic values at other hardness characteristics.

Copper toxicity data with aquatic plants was limited even though copper has been used extensively as an algicide and herbicide for the control of nuisance aquatic plants. The available data ranged from 1 to 8000 µg/L. Most values were higher than the chronic values observed for fish and invertebrate species.

Copper bioconcentration factors ranged from zero to 2000 for the bluegill and the alga (Chlorella regularis), respectively.

Additional data indicated that copper toxicity decreases with increases in alkalinity and total organic carbon. Insufficient data exist however, to mathematically express this apparent relationship.

Modification For Application Within Manitoba

The derived U.S. EPA (1985g) criteria for copper can be applied to water bodies within Manitoba as a water quality objective without modification.

4.7 Cyanide

Existing Objective: 3.5 µg/L, free cyanide (sum of HCN and CN^-), expressed as CN.

Reference: U.S. EPA (1980d).

Revised Objective: 5.2 µg/L, free cyanide (sum of HCN and CN^-), expressed as CN.

Reference: U.S. EPA (1985h).

Rationale: The following was summarized from U.S. EPA (1985h):

Cyanide occurs in water in a variety of forms, such as hydrocyanic acid (HCN), the cyanide ion (CN^-), simple cyanides such as sodium and potassium cyanide, metallocyanide complexes and simple chain and complex ring organic compounds. Free cyanide is the sum of HCN and CN^-. The relative concentrations of these species depends upon temperature and pH. Simple cyanides can readily dissociate and hydrolyze to form CN^- and HCN. However, the metallocyanide complexes have a range of stabilities.

Toxicity towards aquatic life is apparently due to the presence of HCN and CN^- caused by the dissociation, photodecomposition, and hydrolysis of simple cyanide and metallocyanide complexes. The U.S. EPA (1985h) believes that free cyanide is a more reliable form to express aquatic life criteria than total cyanide. Total cyanide includes nitriles and other relatively stable metal cyanide complexes.

Acute toxicity data were available for 17 freshwater species and ranged from 44.73 µg/L for the rainbow trout (Salmo gairdneri) to 2490 µg/L for the chironomid Tanytarsus dissimilis. The Final Acute Value was calculated to be 62.68 µg/L. Because the acute toxicity value for rainbow trout, an important fish species, lies below this value, the U.S. EPA lowered the Final Acute Value to the geometric mean acute value for this species. Thus, the Final Acute Value was 44.73 µg/L.

Chronic toxicity data were available for three fish species and for two invertebrate species. Chronic values ranged from 7.849 µg/L for the brook trout (Salvelinus fontinalis) to 34.06 µg/L for the isopod Asellus communis. An Acute-Chronic Ratio was calculated to be 8.568.

Division of the Final Acute Value by the Acute-Chronic Ratio resulted in a Final Chronic Value of 5.221 µg/L.

Bioaccumulation of cyanide apparently does not occur since it is rapidly metabolized by aquatic organisms.

Modification For Application Within Manitoba

The derived U.S. EPA (1985h) criteria for cyanide can be applied to Manitoba's surface waters as an objective without further modification.

4.8 Lead

Existing Objective: $e^{(2.35[\ln(\text{hardness})]-9.48)}$, total recoverable lead, where hardness is expressed in mg/L as $CaCO_3$ and the resultant objective is expressed in µg/L.

(e.g) 50 mg/L $CaCO_3 \equiv$ 0.75 µg/L
100 mg/L $CaCO_3 \equiv$ 3.8 µg/L
200 mg/L $CaCO_3 \equiv$ 20.0 µg/L

Reference: U.S. EPA (1980e).

Revised Objective: $e^{(1.273[\ln(\text{hardness})]-4.705)}$, acid-soluble lead, where hardness is expressed in mg/L as $CaCO_3$ and the resultant objective is expressed in µg/L.

(e.g.) 50 mg/L $CaCO_3 \equiv$ 1.3 µg/L
100 mg/L $CaCO_3 \equiv$ 3.2 µg/L
200 mg/L $CaCO_3 \equiv$ 7.7 µg/L

Reference: U.S. EPA (1985i).

Rationale: The following was summarized from U.S. EPA (1985i):

Acute toxicity data were available for ten species and ranged from 142.5 µg/L for an amphipod to 235,900 µg/L for a midge. Acute toxicity was found to be inversely related to hardness or to hardness related parameters such as hydroxide, carbonate, calcium, and magnesium. Analyses of covariance was used to relate acute toxicity with hardness for the four species for which data were available. The resultant pooled slope of 1.273 was used to convert all toxicity values to an equivalent value at a hardness of 50 mg/L $CaCO_3$. The Final Acute Value was calculated to be 67.54 µg/L.

Chronic toxicity of lead was also found to be antagonistically related with hardness. Chronic effects, such as spinal deformities, were observed at a lead concentration of 27 µg/L in 32.2% of tested rainbow trout. Similar effects were also observed in life-cycle tests with the brook trout and in an early life-stage test with the rainbow trout.

Acute-Chronic Ratios were available for four species. The geometric mean of the four Acute-Chronic Ratios was 51.29. Division of the Final Acute Value with this Acute-Chronic Ratio resulted in a Final Chronic Value of 1.317 µg/L at a hardness of 50 mg/L $CaCO_3$. The equation $e^{(1.273[\ln(\text{hardness})]-4.705)}$ can be used to derive chronic values for other water hardness characteristics.

Adverse effects of lead on aquatic plants occurred at concentrations ranging from 500 to 63,800 µg/L. Hence, adverse effects on plants occurred at levels substantially higher than at levels that produced unacceptable adverse chronic effects with aquatic animals.

Bioconcentration factors ranged from 42 for the brook trout to 1700 for an invertebrate species.

Modification For Application Within Manitoba

Modification of the U.S. EPA (1985i) derived criteria for lead is not necessary for general application as a water quality objective within Manitoba.

4.9 Mercury

Existing Objective: 0.00057 µg/L, total recoverable mercury.

Reference: U.S. EPA (1980f).

Revised Objective: 0.006 µg/L, total mercury.

Reference: U.S. EPA (1985j), with modifications.

Rationale: The following was summarized from U.S. EPA (1985j):

Mercury is present in aquatic systems in a variety of forms. Inorganic forms include elemental and divalent mercury. Divalent inorganic mercury can be converted to organic mercury forms through methylation by both anerobic and aerobic bacteria within water and within lake and river bottom sediments. Divalent mercury can also be methylated within the slime coat, liver and intestines of fish. Organic forms of mercury have a propensity to accumulate within body tissues of aquatic organisms. It was reported that sorption of mercury from water through gill surfaces is a major pathway for the movement of mercury into aquatic organisms. Additional aquatic life body burden concentrations are probably also obtained from the movement of mercury through the food chain. Demethylation may also occur within aquatic systems such that organic forms of mercury are converted to inorganic forms.

Acute toxicity data with divalent inorganic mercury were available for 28 genera of freshwater animals. Acute toxicity for invertebrate species ranged from 2.2 to 2000 µg/L for Daphnia pulex and three insects, respectively. Acute toxicity for fish ranged from 30 to 1000 µg/L for the guppy and the Mozambique tilapia, respectively. The limited data available indicated that the various organic forms of mercury were between 4 and 31 times more acutely toxic than the inorganic forms.

Chronic toxicity data indicated that methylmercury is more toxic to aquatic life than other mercury forms. Methylmercury was toxic to both Daphnia magna and brook trout at concentrations less than 0.07 µg/L. Divalent inorganic mercury was chronically toxic to Daphnia magna at a concentration near 1.1 µg/L. Acute-Chronic Ratios were greater than 649.2 and 4.498 for the fathead minnow and Daphnia magna respectively, with divalent inorganic mercury and 142.3 for the brook trout (Salvelinus fontinalis) with methylmercury. Aquatic plants were not as sensitive to mercury forms as aquatic animals.

Bioconcentration factors were considerably greater for organic methylmercury than for inorganic divalent mercury. Bioconcentration factors for inorganic divalent mercury were 1800 and 4994 for the rainbow trout (Salmo gairdneri) and the fathead minnow (Pimephales promelas), respectively. Such factors for methylmercury however, ranged from 10,000 to 33,000 for the brook trout (Salvelinas fontinalis), 11,000 to 85,700 for the rainbow trout (Salmo gairdneri) and 44,130 to 81,670 for the fathead minnow (Pimephales promelas).

It was reported that fish body burden concentrations would exceed the U.S. Food and Drug Administration action level of 1.0 mg/Kg prior to aquatic life exhibiting toxic responses following long-term exposure to mercury. Division of this action level by the bioconcentration factor for methylmercury in the fathead minnow (81,700) resulted in a concentration of 0.012 µg/L. Additionally, division of this action level by the bioconcentration factor for divalent inorganic mercury of 4994 resulted in a concentration of 0.20 µg/L. Thus, the U.S. EPA (1985j) recommended that aquatic life and its uses should be protected if methylmercury and divalent inorganic mercury concentration in water not exceed 0.012 µg/L and 0.20 µg/L, respectively for all but a small fraction of time.

Modification For Application Within Manitoba

The action level for mercury in the edible flesh of food fish destined for domestic consumption in Canada is 0.5 mg/Kg as opposed to 1.0 mg/Kg used by the U.S. Food and Drug Administration. Division of Canada's action level by the bioconcentration factors 81,700 and 4994 resulted in concentrations of 0.006 µg/L and 0.10 µg/L for methylmercury and divalent inorganic mercury, respectively.

Most mercury being discharged to the environment is probably divalent inorganic mercury. It is also reported that only a small fraction of mercury in water is in the methylmercury form. Nevertheless, conversion of divalent inorganic mercury to methylmercury can readily occur under natural conditions. Further, numerous mercury in water data collected from a wide geographical range within Manitoba indicated, that with rare exceptions, mercury concentrations were less than the analytical limit of quantitation of 0.02 µg/L. Yet numerous investigations conducted in these and other water bodies, indicated that Canada's action level of 0.5

mg/Kg in the edible flesh of food fish is often exceeded. Consequently, a water quality objective greater than 0.02 µg/L would not appear to offer reasonable protection against the bioconcentration of mercury in the flesh of fish destined for domestic consumption. Adoption of the derived criteria of 0.1 µg/L for divalent inorganic mercury for application as a surface water quality objective within Manitoba therefore is probably too high. The criteria of 0.006 µg/L, derived from methylmercury data, is thought to afford adequate protection to aquatic life and its uses if such a value were adopted as a surface water quality objective within Manitoba. This objective should be expressed as total mercury, hence should apply to all forms of mercury present.

5.0 Revisions to Specific Numerical Objectives, Class 5: Recreation, Category A: Primary Recreation

5.1 Indicator Organisms

Existing Objective:

Fecal coliform bacteria: (a) geometric mean: 200 organisms/100 mL,
(b) individual maximum: 400 organisms/100 mL,
(sufficient samples should be collected to permit valid statistical interpretation).

Reference: Health and Welfare Canada, (1983).

Revised Objective:

(a) *Escherichia coli*: geometric mean: 200 organisms/100 mL.

(b) Fecal Coliforms: geometric mean: 200 organisms/100 mL.

Sufficient samples should be collected to permit valid interpretation.

References: U.S. EPA (1986), with modifications;
Health and Welfare Canada (1983), with modifications.

Rationale:

Recreational waters can become contaminated with microbiological organisms originating from the digestive tracts of humans and other warm-blooded animals. Bathing in contaminated water can result in the ingestion of these organisms which in turn can cause human disease. The most common ailments associated with bathing in contaminated water are firstly, infections of the skin, eyes, ears, nose, and throat and secondly, gastroenteritis. The specific causes of these infections are not well understood, however, the etiological agent responsible for bather-related gastroenteritis is thought to be a virus (Cabelli 1979).

Symptoms of bather-related gastroenteritis are usually relatively benign and include fever, vomiting, diarrhea, and stomach cramps (Cabelli 1979). The symptoms usually last for a relatively short period of time and most patients do not require medical attention (Cabelli 1979).

Because of the technical difficulties associated with analyzing bathing water for specific pathogens, water quality managers have historically used surrogate or indicator parameters as relative measures of the extent of fecal contamination. While such indicator organisms are useful for this purpose, unequivocal association of measured indicator organism densities with the risk of contracting gastroenteritis while bathing is confounded by many variables. These confounding variables include the changing ratios between indicator organism densities and specific pathogens, the changing numbers of infected persons within a given population that may contribute towards the contamination of a bathing area, the variable infectious dose required to cause an illness and the degree of immunity developed by individual bathers. Cabelli (1979) has observed that children under the age of 10 years are more susceptible to bathing-related illnesses than some other groups. This is likely due to their immune defense mechanisms.

Manitoba, along with many other jurisdictions in North America, adopted a water quality objective of 200 fecal coliforms/100 mL during the mid-seventies for the protection of natural bathing areas. Such levels

were rationalized on the basis of tenuous intuitive relationships between fecal coliform densities and bather related illness rates. This approach was logical, even though such relationships could not readily be empirically described.

Recent investigations by researchers in the United States have provided valuable epidemiological information regarding the association of bather-related gastroenteritis with ambient densities of indicator organisms. Cabelli (1981) conducted epidemiological studies at United States marine beaches between 1973 and 1978. A variety of indicator organisms were routinely measured; the strongest relationship was observed between densities of the enterococcus group with gastroenteritis rates amongst bathers. Cabelli (1981) was able to develop a regression equation for this relationship.

Dufour (1983) similarly conducted epidemiological studies from 1978 to 1982 at several freshwater beaches in the United States. Relationships of equivalent good strength were described for both enterococci and Escherichia coli densities with bather-related gastroenteritis rates. Noteworthy is the fact that the slope of the enterococci relationship differed between freshwater and marine beaches. Saline waters are thought to be bactericidal with regard to bacterial indicator organism densities but not with the etiological viral agent.

Dufour's (1983) respective relationships for E. coli and enterococci densities with gastroenteritis rates amongst bathers in fresh waters are as follows:

gastroenteritis rate per 1000 bathers = $-11.74 + 9.40$ ($\log_{10}$ geometric mean E. coli densities/100 mL)

and,

gastroenteritis rate per 1000 bathers = $-6.28 + 9.40$ ($\log_{10}$ geometric mean enterococci densities/100 mL).

These relationships were developed with measured E. coli densities between 15 and 250 organisms/100 mL and with enterococcus densities between 5 and 75 organisms/100 mL. Extrapolation beyond these

ranges would likely not be valid. Regression correlation coefficients are 0.80 and 0.74, respectively. Dufour (1983) also simultaneously examined fecal coliforms in addition to E. coli and enterococci. A relationship was not evident between measured fecal coliform densities and gastroenteritis illness rates amongst bathers ($r = -0.08$).

Cabelli (1983) defined a recreational water quality criterion as a "quantifiable relationship between the density of an indicator in the water and the potential human health risks involved in the water's recreational use". Accordingly, the risk acceptable to Manitoba bathers must first be identified before corresponding indicator organism densities can be calculated. Acceptability of risk is quite variable between individuals. What may be acceptable to one bather may be entirely unacceptable to another. However, because the previously discussed objective of 200 fecal coliforms/100 mL has historically applied to Manitoba's recreational waters, some risk has already been accepted, albeit unknowingly. That is, the risk associated with bathing in water containing a geometric mean fecal coliform density of 200 organisms/100 mL has been unknowingly accepted.

Williamson (1985) discussed the factors to be considered in estimating the risks of contracting gastroenteritis that have apparently been accepted by Manitobans while bathing in fresh water. Williamson (1985) rationalized that, since E. coli was a sub-group of fecal coliforms and that it could conceivably comprise 100% of the fecal coliforms measured at any specific site, then fecal coliforms could be substituted for E. coli into Dufour's (1983) regression equation. Hence, it was assumed that in Manitoba, the risk of contracting gastroenteritis while swimming in water containing either a geometric mean density of 200 fecal coliforms/100 mL or a geometric mean density of 200 E. coli/100 mL could theoretically be similar. Analyses of field data collected from twenty-eight beaches in Manitoba during the summer of 1985 (Williamson unpublished) has confirmed the validity of this approach. Student's t paired difference test was used to assess 1451 data pairs. Fecal coliform and E. coli densities were statistically indistinguishable from one another ($\alpha = 0.05$) at twenty-six of the twenty-eight beaches. At the remaining two beaches, E. coli was slightly more numerous by 9 and 21

organisms. E. coli was analyzed using membrane filtration methods described by Dufour et al. (1981). These authors reported that the method overestimates E. coli at higher densities, thus accounting for this discrepancy. Further, during the summer of 1987, approximately 10 fecal coliform colonies were randomly selected from samples collected from six beaches and one stream on three different occasions and were subjected to confirmatory identification. The data indicated that 218 of 220 such colonies (99.1%) were E. coli. The two remaining colonies were Klebsiella sp. and were isolated on one occasion in samples collected from the Red River downstream of the City of Winnipeg. Consequently, results generated by these methods within Manitoba indicate that fecal coliform data are suitable for substitution into Dufour's (1983) E. coli regression equation without serious error.

Substituting a geometric mean of 200 fecal coliforms/100 mL into the above mentioned E. coli relationship resulted in an estimated risk of 9.9 persons per 1000 bathers contracting gastroenteritis. Williamson (1985) previously identified this risk as 8.2 persons per 1000 bathers contracting gastroenteritis while bathing in water containing either 200 fecal coliforms or 200 E. coli per 100 mL. However, this risk was calculated based on a regression equation developed with data from only two years of Dufour's (1983) three year study.

This identified level of risk (i.e., 9.9 persons contracting gastroenteritis/1000 bathers) can now be substituted into the previously identified relationship between gastroenteritis amongst bathers and enterococci densities. Consequently, an enterococci density of 52.5 organisms/100 mL is associated with a risk of 9.9 persons contracting gastroenteritis amongst 1000 bathers. Thus, the risk of bathing in water containing geometric mean densities of 200 fecal coliforms/100 mL, 200 E. coli/100 mL or 50 enterococci/100 mL is equivalent and is approximately equal to 9.9 persons contracting gastroenteritis per 1000 bathers.

The regression equations and methods described above are similar to those used by the U.S. EPA (1986) to develop new bacteria criteria for United States recreational waters. The U.S. EPA (1986) however, used a slightly lower ratio between fecal coliforms and E. coli to arrive at an approximate presently accepted risk level of 8 persons contracting

gastroenteritis per 1000 United States bathers. Given this estimated risk level, the U.S. EPA (1986) recommended E. coli and enterococci geometric mean criteria densities of 126 organisms/100 mL and 33 organisms/100 mL, respectively.

However, while the results of Cabelli (1983) and Dufour (1984) represent significant advances with regard to linking bather related gastroenteritis with indicator organism concentrations, acceptance of the findings have not been universal. Lue-Hing et al. (1984) have criticized a number of the methods used by these researchers including the statistical methods used to analyze the data and the failure of the study designs to account for a number of confounding variables.

Epidemiological studies are nearing completion in Canada that appear to have utilized a superior study design (Seyfried and Brown 1985). While the results are still preliminary, Brown (pers. comm.) has indicated that their results differ from those of Cabelli (1983) and Dufour (1983) in a number of important areas. Firstly, a relationship was observed between bather related gastroenteritis and fecal coliform densities and secondly, a relationship was not evident between bather related gastroenteritis and enterococci densities. The preliminary logistic relationship between bather related illness and fecal coliform density is as follows:

$$\log_e \left\{\frac{p}{(1-p)}\right\} = 0.347 \log_{10}(\text{fecal coliform densities/100mL}) - 4.752,$$

where p is the probability of becoming ill. This relationship predicts that 19 persons out of 1000 bathers could contract gastroenteritis following swimming in water containing a fecal coliform density of 200 organisms/100 mL.

Because of the uncertainty surrounding the various epidemiological studies, surface water quality objectives will not be recommended for enterococci at present. However, water quality assessments of recreational areas should include analyses for enterococci and the results should be compared to the derived objectives for enterococci (i.e., 50 enterococci/100 mL) discussed above.

Water quality objectives for microbiological indicators have usually been expressed as an average based upon a minimum number of samples collected over a specified period of time (e.g., 5 samples equally spaced in time during a 30-day period) (U.S. EPA, 1976; Health and Welfare Canada, 1983). This method attempted to recognize the variable nature of bacterial populations in surface waters and the imprecision of the sampling and analytical methods.

The objectives discussed here will be merely specified as the geometric mean of an unspecified number of samples, sufficiently large however, to permit valid statistical interpretation of the data. The choice of sample size therefore depends largely upon the variability of the bacterial population densities and the confidence required for data interpretation purposes. The length of the averaging period also will not be specified. These objectives are useful for determining compliance during various averaging periods (i.e., 1 day, 5 days and 30 days, etc.) without being sufficiently different from the original epidemiological study design of Dufour (1983) so as to expect different gastrointestinal illness rates at similar indicator densities.

Methods for determining sample size have been described by various authors; the methods of Youmans (1973) are satisfactory. Table 3 provides a comparison of sample sizes required to determine that the water quality objective has been exceeded with the corresponding degree of confidence and that remedial action may be warranted.

Table 4: 60% and 90% one-tailed upper confidence limits and corresponding sample size required to determine non-compliance with bacterial indicator organisms in recreational waters.

Objective	Sample Size(n)							
	1[a]	2	8	12	25	50	100	200
50 enterococci/100 mL								
60% one-tailed upper confidence interval[b]	71	69	57	56	54	54	52	51
90% one-tailed upper confidence interval[c]	293	1013	100	86	72	72	60	57
200 fecal coliforms/ 100 mL or, 200 E. coli/100 mL								
60% one-tailed upper confidence interval[d]	252	247	218	214	210	207	205	203
90% one-tailed upper confidence interval[e]	650	1486	318	287	255	237	225	217

(a) The values in this column should be used to assist in determining when re-sampling may be required.

(b) For n = 1

$= \text{Log}_{10}[50] + [Z = .253\ (0.6)]$

For other n's

$$= \text{Log}_{10}[50] + \frac{(t_{n-1};\ \alpha = 0.60)(0.6)}{\sqrt{n}}$$

(c) For n = 1

$= \text{Log}_{10} [50] + [Z = 1.28\ (0.6)]$

For other n's

$$= \text{Log}_{10} [50] + \frac{(t_{n-1};\ \alpha = 0.90)(0.6)}{\sqrt{n}}$$

(d) For n = 1

$= \text{Log}_{10} [200] + [Z = .253\ (0.4)]$

For other n's

$$= \text{Log}_{10} [200] + \frac{(t_{n-1};\ \alpha = 0.60)(0.4)}{\sqrt{n}}$$

(e) For n = 1

$= \text{Log}_{10} [200] + [Z = 1.28\ (0.4)]$

For other n's

$$= \text{Log}_{10} [200] + \frac{(t_{n-1};\ \alpha = 0.90)(0.4)}{\sqrt{n}}$$

Please note the $\log_{10}$ standard deviations of 0.6 and 0.4 for enterococci and *E. coli*/fecal coliform respectively were calculated from approximately 1500 samples collected from 28 beaches in Manitoba during 1985.

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APPENDIX A

Manitoba

Clean Environment Commission

Chairman

Box 4
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R3N 0H6

(204) 945-7120

File: 1875.1

September 11, 1985

The Honourable Gerard Lecuyer,
Minister of Environment and
Workplace Safety and Health,
156 Legislative Building,
WINNIPEG, Manitoba.
R3C 0V8

Dear Mr. Lecuyer:

Further to my letter of August 6, 1985, attached herewith is the Commission's report with recommendations on its review of provincial water quality objectives.

Yours sincerely,

Stan Eagleton,
Chairman.

REVIEW OF SURFACE WATER QUALITY OBJECTIVES FOR MANITOBA

The Clean Environment Commission

September, 1985

- C O N T E N T S -

INTRODUCTION 1

SUMMARY AND RECOMMENDATIONS. 2

HISTORY OF THE WATER QUALITY MANAGEMENT PROGRAM. 12

ACCOUNT OF THE PUBLIC HEARING. 14

APPENDIX A LIST OF EXHIBITS 34

APPENDIX B CHANGES BY ENVIRONMENTAL MANAGEMENT DIVISION SUBSEQUENT TO HEARING. 35

INTRODUCTION

Water is a vital element of our environment. Biological existence of humans and all land-based life is dependent on water; it is required to support fish and other aquatic life; agricultural production is dependent upon it; it is important in both energy and industrial production; it is the basis of much recreational activity and it is a key element in terms of aesthetic considerations. Contaminated water poses a threat to all of these uses and may require costly treatment to render it satisfactory to protect human health and a wide variety of other uses. Throughout the world, including the North American continent and parts of Canada, an adequate supply of good water can no longer be taken for granted. Water quality management objectives are designed to protect, maintain and improve its quality for its various essential uses.

Public hearings to examine Manitoba's surface water quality objectives (1979) were held November 20 and 21, 1984, in Winnipeg during both daylight and evening hours. Approximately fifty people were in attendance during the course of the hearings with over seventy-five percent representing government departments, fifteen percent industry and the balance private citizens.

Copies of a revised water quality management proposal, prepared by the Environmental Management Division, had been sent out to appropriate government organizations, industries, and environmentally related groups well in advance of the hearings. The hearings were advertised in the print media some two to three weeks ahead of the hearing dates.

The hearings were convened under Section 13(1) of The Clean Environment Act at the request of the Minister, The Honourable Gerard Lecuyer, Minister of Environment and Workplace Safety and Health, in accordance with procedures recommended in the Commission's original 1979 surface water quality objectives report.

SUMMARY AND RECOMMENDATIONS

The Importance of Water Quality Objectives

There was some disagreement about the surface water quality objectives among the respondents. A number of the respondents felt that numbers should not be set to cover a variety of water courses and conditions; that each reach of water should have objectives set on an individual basis. Water quality objectives have been a very useful tool in managing water quality in Manitoba since their implementation in 1979. In the United States, water quality standards have been the major tenet of the Clean Water Act for over a decade.

« Recommendation

Water quality objectives should continue to be used in Manitoba and revised as better information becomes available.

Unlike the standards promulgated under the Federal Clean Water Act in the United States, the Manitoba objectives are not legally enforceable; however, they provide guidelines or targets to be used as part of the overall assessment of the quality of a receiving stream.

Water Quality Monitoring and Stream Classification

Almost every submission emphasized the importance of accompanying the objectives program with a program for both stream classification and water quality monitoring. As a result of a change of priority in programs in the Environmental Management Division, the Water Standards and Studies Section, which has the responsibility for water quality monitoring and preparing the documentation for the classification of water courses, has had its resources significantly reduced. Monitoring has been seriously curtailed as well as the preparation of the documentation for continuation of the classification streams and watersheds in Manitoba. Only three of

Manitoba's nineteen watersheds have been classified and, in light of possible changes to the objectives, it may be necessary to review these classifications.

« Recommendation

The Commission strongly urges that the previous network water quality monitoring program be resumed as soon as possible and that classification of surface water courses be restarted so that within some reasonable time period (possibly ten years) all of the Manitoba watersheds will have been classified. In the interim, the Division should deploy as many resources as possible to assist in the classification of important segments of water courses. In all cases of classification and reclassification, public hearings should be held before the Commission followed by a report including recommendations made by the Commission to the Minister.

Format of the Objectives

The original report combined surface water quality objectives and stream classification. For the purpose of clarity and for convenience in administration, the Division has now proposed that the "objectives" document be separate from the "classification" document.

The importance of revising the document in the light of new knowledge and technology was also addressed by many of the respondents as well as the Environmental Management Division.

« Recommendation

The Commission agrees that water quality objectives and stream classification are two distinct parts of a single program and that there is good, practical sense in having two separate documents. Volume II, the classification document, did not come under direct scrutiny during the present review. Revisions should take place as warranted by new knowledge.

The Commission also agrees with the Division's suggestion that Volume I and Volume II, once revised and approved, should be separate documents, not published together with the Commission's report on the proposal. The previous publication of the Commission's report in the same booklet with the objectives and classification proposal made the document unnecessarily voluminous and complex.

Procedure for Future Revisions of the Objectives

During the initial development of both the objectives and classification process, documentation was prepared by the Environmental Management Division and reviewed by an advisory committee consisting of provincial government departments with an interest in water quality management. The Water Quality Advisory Committee is made up of representatives of the Water Pollution Control Section of the Environmental Management Division, Manitoba Departments of Agriculture, Municipal Affairs, Health, Urban Affairs, Economic Development & Tourism, Energy & Mines, and Natural Resources. The Commission circulated the document widely and held a hearing to receive input from any respondent. The resulting document, "Report on a Proposal Concerning Surface Water Quality Objectives and Stream Classification", based on the proposal and public responses received became the official publication of The Clean Environment Commission with the water quality objectives being an appendix to the document.

One of the recommendations of that original report was that revisions should occur every three years. The present review results from that recommendation in the original report. The Division now recommends that, for future revisions, the initial step would be documentation supporting a proposed revision, which might originate either from the Division or from an outside agency. The documentation would be considered by the water quality objective advisory committee who would decide whether the revision is warranted. The document would then be reviewed by the

Commission who would decide whether further distribution is necessary and whether a public hearing should be held. The final revised document prepared by the Division would then be forwarded to the Minister for a policy decision with the final step being the circulation of the revisions to the registered "holders" of the objective document.

At the hearing, Manitoba Hydro indicated their ongoing interest in the water quality management program and a desire to be a included in the membership of the Advisory Committee.

« Recommendation

The Commission recommends that, in future, revisions to the objectives document be handled as follows:

1. Documentation supporting revisions would first be submitted by the proposer of a change.
2. The proposal would be considered by the Water Quality Objectives Advisory Committee.
3. If a revision seems desirable, The Clean Environment Commission would review the proposal internally. If warranted, The Clean Environment Commission would then decide to circulate the revision proposal widely and conduct a public hearing.
4. A final document would then be prepared by the Division and reviewed by The Clean Environment Commission before referral to the Minister for policy implementation.
5. Revisions would be circulated to registered "holders" of the objective document.

The Commission also recommends that Manitoba Hydro should be represented in the membership of the Water Quality Objectives Advisory Committee.

Concerns with Respect to Specific Constituents and Concentrations

Many respondents asked both specific and general questions concerning the numerical value selected by the Division as the limit for a number of water constituents. There were also questions about constituents such as dioxins and furans that were not covered by the document. The Division noted that, as a need to deal with such constituent levels arose and with the development of criteria for such constituents, they would be added to the list of objectives.

The Ducks Unlimited representative felt that the values should be as low as possible because of the lack of knowledge in many cases of synergistic and additive effects. It was noted that the criteria utilized (principally USEPA) did take into account these effects, where known, and that, in most cases, where toxicity was involved, a significant safety factor was employed.

Some of the values of constituents such as heavy metals are below the detection capabilities of laboratories. One respondent felt that it was improbable to include values that could not be measured in the water column. The Division's reply was to the effect that, although the values cited could not be measured analytically, water quality criteria documents specified these concentrations as being necessary to support an aquatic ecosystem. Such values would still have use in mathematically computing the loading of such substances to a water course.

Several people questioned the use of criteria that was developed in the United States (USEPA) as being applicable to Manitoba, especially that with respect to the protection of aquatic life. The Division's response was that most of the better information available was based on studies undertaken by the United States Environmental Protection Agency.

The City of Brandon took exception to the value for un-ionized ammonia (.02 milligrams per litre un-ionized ammonia as NH_3) to protect a cool water fishery. The Division indicated that even recent information received from their technical counterparts in the United States supported this value.

Microbiological limits were questioned by the City of Winnipeg. The faecal coliform limit of 1000 per 100 millilitres for secondary contact recreation was based on best professional judgement. The same limit for the irrigation of vegetable crops was based on the National Academy of Science Water Quality Criteria document of 1972. The Division was supported in its position that a faecal coliform limit should be applied to the irrigation of vegetables by the Health Department.

There was also a proposal by a representative of the Department of Fisheries and Oceans that some constituents should have different seasonal objective limits because of seasonal fluctuations in the water ecology.

« Recommendation

The Commission believes that the list of constituents and their concentrations currently proposed by the Division in the objectives document are reasonable given the complexity of the surface water quality objectives development program, the fact that a revision procedure will also be in place, and also that the document sets out target guidelines rather than standards.

The Commission further recommends that the Division should consider the advisability of developing different seasonal limits for some constituents.

Concerns with Some Concepts of the Objectives

A number of concerns were expressed by respondents who represented organizations which utilize receiving waters for the purpose of waste discharges, for example, the Cities of Brandon and Winnipeg, Manitoba Hydro, and the mining industry. All felt that the mixing zone concept should be handled on an individual basis, which, in fact, is the recommendation of the proposal document; however, the document also includes a list of guidelines which it is stated "should apply to mixing zones where applicable".

The Mining Association was unsatisfied with a High Quality and Exceptional Value Waters category. The "exceptional value" category disallows any degradation. Mining development is therefore virtually prevented. They believe that a classification of this or any type should involve a hearing with an opportunity for anyone to present their views as to the soundness of the recommendation.

Manitoba Hydro felt that the examples given for "exceptional value" waters, for example, scenic rivers or habitat for rare flora or fauna, could be applied to many waters and there was, therefore, a danger of overutilization of this category.

As regards the category, "high quality water", the Mining Association had a concern that any project such as mining would have difficulty with the required waste treatment and discharge regime since the requirement to utilize "best available technology" does not carry with it a cost/benefit evaluation, unlike the term "best practicable technology".

In terms of the general requirements covering toxic substances, (Section 1.7), the Mining Association felt that the general requirement that all waters should be, "free from substances in concentrations or in combination that injure, are toxic to, or produce adverse physiological or behavioral responses in humans, aquatic, semiaquatic, and terrestrial life", would severely limit all discharges to the aquatic environment.

With regard to the "nutrients" section, the City of Winnipeg felt that the technology was not in place to determine what phosphorus values were limiting. The use of unsubstantiated numerical values could lead to misinterpretation which might even bring well-qualified numbers into question. The City also felt that there was a confusion in the "domestic water" category by the inclusion of a value for faecal coliforms. All other constituents were those applicable to treated drinking water.

Both Manitoba Hydro and the Mining Association seriously questioned the objectives in general; the Association for reasons that the numerical value of objectives should have received more extensive peer

review and Manitoba Hydro because they felt that discharges to receiving waters could not be handled by numerical values applied universally, advocating that each case should be handled on an individual basis.

The Mining Association also expressed some difficulty with the statement that disallows the discharge of a constituent in a concentration exceeding that of the receiving water where the natural state level exceeds the level in the objective. The Division's answer to that concern was that treatment might be employed to reach the natural level or another receiving medium might be used. In that the document provides guidelines rather than standards, a decision might also be made on a site-specific basis to waive the objective requirement proposed.

In the statement on the application of the objectives to an intermittent stream, "When the intermittent stream does not contain this flow, the objectives to be maintained should be those pertaining to the water body to which the intermittent stream is tributary", the proposal document did not make it clear whether the objectives are to be met in the tributary stream where the flows are critically low or at the confluence with the main stream. It was assumed that the latter is intended but this required clarification.

« Recommendation

The Division has reviewed the material presented at the hearing and provided subsequent comments and revisions to the objectives (Appendix B). Notwithstanding this, as a result of the Commission's consideration of the arguments and evidence received during and subsequent to the hearings, the Commission believes that there are unresolved questions about the practical application of parts of the proposal, as follows:

1. Mixing zones
2. Minimum flow
3. High and exceptional quality water designations
4. The mix of raw and finished drinking water quality objectives (faecal coliforms)
5. The definition of toxic substances and nutrients in Section 1.7

The Commission, therefore, recommends that the Environmental Management Division further examine these matters, in consultation with the Water Quality Objectives Advisory Committee and review the resulting findings with the Commission.

Status of Presently Classified Watersheds

Although only three watersheds have been classified to this point, there have been some major changes proposed to the objectives document. There may be reason to believe that there is a requirement to review the classifications assigned to these waters. This was suggested by the Town of Selkirk in connection with the new category for primary contact recreation.

« Recommendation

The Environmental Management Division and The Clean Environment Commission should discuss and decide on the need, importance and method of reclassifying already classified watersheds.

Interjurisdictional Waters

Both at the hearing and subsequently, it was noted that most of the watersheds in Manitoba were linked to interjurisdictional waters crossing Manitoba's boundaries with Saskatchewan, Ontario, and the United States. It was recommended that attempts be made to ensure that water quality objectives developed at or above the boundaries should correlate with the Manitoba objectives.

« Recommendation

The Division should ensure that Manitoba objectives are correlated with objectives developed on an interjurisdictional basis and report to the Commission in this regard.

HISTORY OF THE WATER QUALITY MANAGEMENT PROGRAM

The development of water quality objectives and a stream classification system for Manitoba was started in 1977. At that time, the Environmental Management Division prepared detailed documentation that was sent to interested individuals, environmentally related groups, industries and municipal governments.

The Clean Environment Commission held a hearing in Winnipeg in June of 1977 to review this proposal. Most of the representations at the hearing were made by professionals from government and industry.

The outcome of the process resulted in The Clean Environment Commission's "Report on a Proposal Concerning Surface Water Quality Objectives and Stream Classification for the Province of Manitoba", completed in late 1978 with revisions in May 1979. Nineteen water basins were identified as drainage areas to be classified for water quality purposes.

Subsequently, the classification process was carried out for the Souris, the Red and the Grass and Burntwood River systems in 1979 and 1981.

The establishment of water quality objectives has been given increasing attention by the federal government and many of Canada's Provinces. There are water quality standards in place in every state in the United States under the aegis of the Federal Clean Water Act. In Canada, there are regulations under the federal Fisheries Act pertaining to the quality of effluent from a number of specific industries, but there are no national water quality objectives or standards. However, the federal government has established a water quality objectives directorate with branch offices across Canada working with the Provinces and the United States on the development of objectives relating to interjurisdictional boundary waters. A new federal standard for drinking water is currently under consideration. The existing guidelines for Canadian drinking water quality were prepared in 1978 by a federal/provincial working group. Manitoba was the first Province to develop formal water quality objectives

and subsequently apply them to the classification of specific watersheds. It is, therefore, in the forefront in this respect.

The Commission's 1979 report recommended that the water quality objectives be reviewed every three years by the Environmental Management Division for the purpose of considering possible revision as warranted by new evidence and that, prior to any revision, interested parties should be given the opportunity to present their views.

This review of the Surface Water Quality Management Proposal was undertaken by representatives of the Environmental Management Division in collaboration with a number of other government departments resulting in the publication of two separate volumes in 1983, "Surface Water Quality Objectives" and "Watershed Classifications". The November 1984 hearing dealt only with Volume 1 of the proposal - "Surface Water Quality Objectives", as the program to classify Manitoba's watersheds has been temporarily curtailed.

ACCOUNT OF THE PUBLIC HEARING

A public hearing was held in the Norquay Building auditorium in Winnipeg on November 20 and 21, 1984. Clean Environment Commission members present were Mr. Stan Eagleton, Chairman, Dr. George Bowen, Prof. Ray Chant, Mrs. Mamie Hendren and Dr. Barrie Webster.

A number of formal written submissions were received at the hearing and these are listed in Appendix A. In addition, a number of verbal presentations were made. The following is an account of the submissions received.

§ Environmental Management Division

Mr. Dwight Williamson, an Environmental Officer with the Water Standards and Studies Section, presented the new revised Surface Water Quality Management Proposal. Mr. Williamson was the principal author of this proposal. He stated that a basic use of water quality objectives is as a planning tool to avoid further contamination, while maintaining a balance with socioeconomic development.

Surface waters in Manitoba are used for many purposes - domestic consumption, industrial uses, agricultural use, as well as recreational, fishery and wildlife use. These uses can be harmfully affected by changes in water quality. Surface water quality objectives define minimum levels of quality for each of the uses that are to be protected.

Water quality objectives were developed for over eighty specific constituents and eight general groups of contaminants. If the objectives are under protective, water quality may become degraded. If, however, they are overprotective, an unnecessary burden may be indirectly imposed on taxpayers.

Objectives are used largely by government agencies to control practices that may have effects on water quality. The objectives are also

used by government departments to help determine if certain waters are acceptable for specific uses.

It was advocated that readily treatable waste, should not be permitted to be discharged into a watercourse in an untreated state, even though such untreated waste might not result in an exceedance of the water quality objectives.

Direct legal recourse is not available in cases where the objectives are not being met. Orders can be made by The Clean Environment Commission, or regulations can be made under The Clean Environment Act, to provide legally enforceable limits or standards to protect water quality where legally enforceable standards are needed to control point sources of contamination.

The water quality objectives are intended to be applied to anthropogenic substances. However, where the concentration of a constituent in the natural state is already above the level specified in the objective, it might be undesirable to add further to that burden.

It is desirable that objectives be revised periodically as new, scientific information becomes available.

Objectives have not been developed for all possible constituents that could affect water quality. However, if it were demonstrated that such constituents are present, objectives would then be developed using the best available scientific information.

Objectives are not intended to apply under all flow conditions nor in mixing zones which are areas adjacent to point sources of effluent discharge. Guidelines are provided, however, to ensure that the loss of water quality is kept within acceptable limits. The specific low flow chosen below which certain objectives cannot reasonably be expected to be met is defined as the lowest flow occurring for a seven day period once every ten years. For small intermittent streams, the minimum flow is 0.003 cubic metres per second (40 gallons per minute). In lakes, the objectives should be maintained at all times.

Pristine waters, such as those that may exist within provincial parks, may be given a "high quality" designation with the intent being that discharges or other activities that affect water quality should be strictly controlled. An "exceptional value" designation may be placed on waters that should be preserved in their natural state.

Specific numerical objectives cannot be developed for every possible parameter, therefore, general statements have been developed for such components as colour, odour, taste, turbidity, et cetera, such that appropriate, beneficial use will not be impaired.

It is recommended that care should be taken to see that water management projects such as dams, diversions, et cetera, do not seriously impair water quality. Nutrients should be limited to the extent that nuisance growths and overabundance of aquatic vegetation are prevented.

Objectives have been developed for each of the designated general surface water uses - domestic consumption, industrial use, agricultural use, and for fishery, wildlife, and recreation use. In several cases, these classes are further subdivided.

In the domestic consumption class, the objectives enumerated ensure the protection of waters that are suitable for human consumption after treatment. Objectives have been included for both aesthetic and health considerations. It is assumed that minimum treatment consisting of disinfection is required for all surface drinking water supplies, prior to consumption. All of the constituent values listed, aside from bacterial limits, are expected in a treated water supply.

The aquatic and wildlife category, is subdivided into two categories; (a) cold, cool water aquatic life; and (b) cool water aquatic life. The first category would protect the salmonidae such as the trout and whitefish whereas the second category would protect only more resistant species. The only real difference between the two categories is in terms of dissolved oxygen requirements.

As a consequence of the large number of industrial users (current and potential) many having different water quality requirements, objectives were not developed for this classification at the present time.

Agricultural consumption is divided into four categories - three for irrigation and one for livestock. Differences in the irrigation category are principally a function of the soil type.

In the recreational category, primary body contact activities (swimming, water skiing) and secondary body contact activities (boating, fishing) are handled separately. Bacterial levels and clarity are the main water quality objective differences.

Mr. Williamson reviewed the main revisions of the "objectives" document as follows:

- There are now two distinct and separate documents in place of one.

- The introduction has been considerably expanded providing a basic description and an explanation as to how the objectives are to be used, for example, their application in the event that constituents exceed the objective level in the natural state.

- The term "nondegradation" has been replaced by a "high quality" designation in which discharges should be stringently controlled and an "exceptional value" category in which discharges should be discouraged.

- A section discusses the desirability of developing objectives as may be necessary for substances which are presently excluded due to a lack of information or because they are not now known to be present in Manitoba waters.

- General objectives have been added for characteristics such as flow, litter and nutrients. The nutrients section replaces a nutrients policy in the previous document.

- In addition to the minimum flow guideline tabled in the previous report, a minimum flow has been proposed for intermittent streams.

- Further guidelines have been included in the mixing zone section of the report.

- In terms of the individual classes of water use, there have been a number of changes. Four categories in the domestic consumption category have been reduced to one. In place of specifying constituent limits for raw, untreated drinking water, the limitations, apart from bacterial limits, are based on treated drinking water. The fisheries and recreation category has been changed to exclude recreation in this category, however, wildlife is included. Wildlife was formerly grouped with agricultural consumption. In the industrial consumption category, the three categories formerly utilized have been deleted. Objectives for industries will be established on a site-specific basis in place of the former three categories. Agricultural consumption, with the wildlife use category removed, is broken down into four categories with three having irrigation application and the fourth being related to livestock consumption. Recreation, in place of accompanying fisheries, is now a separate entity with a subdivision for primary and one for secondary body contact recreation.

- Numerous revisions were made to specific numerical objectives to reflect current scientific thought. Some changes were also included in terms of the form of measurement of a constituent, for example, "total", "dissolved", "extractable".

- Volume II, which deals with the classification of water courses, is now separate from the main report on objectives. Although the present allocation of resources within the Environmental Management Division, will not permit the continuation of a program for the classification of all watersheds, the Environmental Management Division is able to make a limited commitment to the classification of important segments of watersheds on a site-specific basis.

A number of questions were raised concerning the Division's revised surface water quality proposal. One questioner felt that the limits should apply at all flow conditions. In response, it was noted that it would be a major economic hardship to meet the pollution load allocation in order to protect very low flows. General objectives such as appearance and odour would, however, be applied at all flow conditions. Another questioned the value of the exercise of reexamining the objectives in the light of absence of funds to continue with full scale classification of the water courses.

Some discussion followed concerning a proposed procedure for handling revisions to the surface water quality objectives. The first step proposed would be documentation supporting a proposed revision which might originate within the Environmental Management Division or from outside agencies. The document would be circulated to the water quality objectives advisory committee who would decide whether further scrutiny was warranted. The draft document would then be submitted to The Clean Environment Commission for internal review. The Commission would decide whether, in addition to distributing the report to interested individuals or agencies, a public hearing should be held. A final revision document would then be prepared by the Environmental Management Division and submitted to the Minister for a policy decision. The final revision would then be forwarded to all those with registered "objective" documents. This was also the Environmental Management Division's recommendation for the current review which is a departure from the original practice under which the document was published under the aegis of The Clean Environment Commission.

In response to a question as to the origin of numbers for specific objectives, Mr. Williamson noted that the available criteria documents from other jurisdictions were reviewed, principally those of the United States Environmental Protection Agency, Health and Welfare Canada, Environment Canada, and the National Academy of Science. A decision was then made as to whether these criteria were suitable for Manitoba conditions. In several instances, where specific numbers applicable to Manitoba were not available, best professional judgement was employed.

§ Environment Canada

A representative from the Water Quality Objectives Division of Environment Canada, Regina, Dr. K. W. Thomson, spoke on behalf of that Department. He endorsed a number of points made by the Environmental Management Division that the objectives are an important guideline for setting effluent limits and a valuable informational tool. It is also important that upstream and downstream jurisdictional interests are taken into account, for example, those relating to the Province of Saskatchewan. Monitoring and assessment are also a vital part of the water quality objectives and classification program.

He expressed a concern that the use of the terms "assimilative capacity" and "dilution factor" should be carefully examined in the document since there is a basic difference between the two expressions.

He believed that the objectives should single out the sublethal effects of contaminants as well as lethal effects. In this connection, he referenced the Prairie Provinces Water Board and the use of what is termed an ALERT level which serves as a trend of sublethal or chronic toxicity. The Environmental Management Division representatives, in response to this statement, pointed out that the maximum acceptable concentration of constituents to protect aquatic life is based on information derived from both acute and chronic toxicity tests.

Dr. Thomson noted that the Federal Government is also interested in the maintenance and enhancement of water quality through objectives viz responsibilities under Section 33 of the Fisheries Act, International Boundary Waters, Federal properties.

Environment Canada does not view favourably such phrases as "mixing zone", "assimilative capacity" or "zone of influence" with respect to effluent discharges to water bodies. Federal legislation respecting effluent control has long endorsed the principle of containment at source. Control standards are based on best practicable technology which takes into account technical feasibility and economics.

§ Ducks Unlimited

A representative from Ducks Unlimited, Dr. Rick Wishart, felt that the objectives should contain a stronger statement about wetlands and water quality values.

Synergistic and additive effects of contaminants are a very serious matter. Such factors make it necessary to ensure that contaminants are present at minimum levels. Polluters or the regulatory agency should have to show that combined levels of contaminants are acceptable.

He noted that it seems contradictory to develop a set of objectives and, at the same time, reduce the technical staff necessary to administer the program.

In terms of classification, he expressed the view that watersheds are too large to be handled as a single unit. Small individual stream, lakes, marshes and potholes within a watershed are given a single classification but should be considered individually.

§ Manitoba Mining Association

The Manitoba Mining Association representative, Mr. Wint Newman, suggested that the objectives should reflect not only environmental protection requirements but also practical social and economic needs of the regions involved.

He expressed the Association's concern about the principle that water courses should not be further impaired where the natural constituents are already at or above the objective levels. All human activity could be precluded in such an area due to natural causes.

He believed that there was a contradiction in the statements about mixing zones which specify that effluents should not produce adverse responses; whereas a mixing zone, by definition, is a zone within which degradation is allowed.

He stated that water basins that have already been classified should not be reclassified according to the new proposal before public input is sought, for example, the Grass and Burntwood River systems.

The Association felt that the "high quality" classification in the new proposal suggests that operations would have to employ "best attainable treatment" to meet the requirements, which concept does not entail a cost/benefit evaluation.

The Mining Association believed that the review of the numerical values of the objectives may be inadequate. A special peer review panel should be appointed for this purpose with representatives from all interested parties. In response to this point, the Environmental Management Division representative felt that there has been a peer review process. An interdepartmental advisory committee has been involved with the preparation of the document and the document was circulated to other jurisdictions including the environment departments of all provinces.

The Association also wanted to see more of the values, especially for cold water aquatic life, referenced to Canadian sources. Of thirty-one chemical elements, 85 percent of the values originated from criteria developed by the United States Environmental Protection Agency. Some of the United States numbers are still under review and subject to changes. The Division responded by saying their position is that the testing protocol in the United States is superior to elsewhere. Where United States information was not available, Canadian or other guidelines were used.

The Association also questioned the setting of objectives below the capability of laboratories to measure them. As an example, cadmium has a detection limit of .001 milligram per litre, yet the limit for cold water aquatic life at a hardness of 100 milligrams per litre is .000025 milligrams per litre - an order of 100 times less than the objective.

Mr. Newman was also concerned about changing the objectives as new information becomes available. This could produce an economic hardship for an operation such as an existing mine.

He expressed the opinion that provision should be made for start-up situations when it might not be possible to control the mining process and effluent to the degree achievable on an ongoing basis.

He was also concerned about the definition of mixing zones because he felt that the general requirements concerning toxic substances should not apply to this section. The definition for toxic substances states that water shall be free from substances in concentrations or combinations that injure, are toxic to or produce physiological or behavioral responses in human, aquatic, semiaquatic and terrestrial life. The Association supported the concept that acute toxicity should not be tolerated in a water course but believed that some of the subtle effects expressed in the definition of toxicity would be difficult to meet.

§ City of Brandon

A representative of the City of Brandon, Mr. Ted Snure, Assistant City Engineer, questioned the necessity of the safety factor built into some constituents in the objectives. He felt that the Manitoba waters were being overprotected and cited the example for un-ionized ammonia at 0.02 milligrams per litre (NH_3) which value is 0.1 of the LD_{50} of a sensitive organism such as a trout or salmon. He also claimed that even the mixing zone concept leads to overprotection of waterways. There are thirteen guidelines concerning mixing zones and he believes that the combination of these with the Division's policy that the objectives should protect the most sensitive use - contributes to overprotection.

Mr. Snure summarized his position in a number of statements.

- Each reach of receiving water should be examined in terms of its unique characteristics and objectives set accordingly in place of a single set of numbers on each classification.

- In place of guidelines for mixing zones, each area should be evaluated on a site-specific basis.

- As applications to discharge effluent to water courses reach the Commission, the classification process should be undertaken ensuring that public input will be solicited in the process.

- Although the objectives are meant to be guidelines, they are invariably used by the Division as a basis for the establishment of rigid standards. In this regard, he believed that the un-ionized ammonia limit should remain at 0.02 milligrams per litre (N) and that the Division should undertake studies to establish a Manitoba numerical value for ammonia.

The Division responded to a number of points raised by Mr. Snure in his representations. In terms of overprotection and safety factors, the application factor applied to the acute toxicity data provides a level that protects against chronic effects. In terms of un-ionized ammonia, the Division maintains the position that the level should be established at .02 milligrams per litre (as NH_3). United States studies support the position that walleye and sauger are no less sensitive to ammonia than trout and the limit was predicated on the sensitivity of members of the trout family.

§ Manitoba Environmental Council

Mr. Mike McKernan, Acting Chairman of the Environmental Chemicals, Water and Waste Committee, made the presentation of the Environmental Council.

Perhaps the most important item raised by Mr. McKernan was a need for additional resources in the Environmental Management Division to carry out the surface water quality program including a long-term commitment to monitoring and the ability to analyze low levels of toxic substances. The Council was concerned about a number of classes of compounds, such as PAH's, dioxins, furans and phthalate esters, for which there are no guidelines. In some instances, these compounds were known to degrade, forming intermediate products that are more dangerous than the original compounds. The Council representative also expressed a concern about the analytical capability of the Province to quantify or speciate compounds such as those named above as well as others. Without the capability to analyze such compounds, there would be no capability to measure compliance.

He expressed the belief that it is important for Manitoba to remain in the forefront with respect to surface water quality objectives and that objectives should be developed for specific constituents in advance of an order of the Commission involving any constituent.

In response to the Manitoba Environmental Council presentation, the Division representative noted that Manitoba was endeavouring to remain in the forefront with respect to the development of objectives and also to ensure an adequate analytical capability. However, the process is very, very costly in terms of manpower and equipment.

§ City of Winnipeg

The City of Winnipeg representative, Mr. Barry McBride of the Waterworks, Waste and Disposal Branch, expressed a concern similar to others that the objectives which are intended as guidelines seem to be applied automatically as standards. There was also some concern that some of the objectives are quite arbitrary. The City also contended that a water course which, in its natural state, is not suited for a particular use should not be protected for that purpose, for example, primary recreation where water clarity does not make this a suitable activity.

The City advocated that the exceptional value water category should include not only the protection of exceptional recreational and ecological values but also the protection of a resource value such as a drinking water source. This reflects a desire on the part of the City to prohibit development around Shoal Lake which is the source of drinking water for the City of Winnipeg.

He stated that the inclusion of numerical values for phosphorus in the nutrients section under general requirements is not supportable and could lead to misinterpretation. Eutrophication is site specific and its control is complex and he did not believe that numerical values can be supported in use-related objectives.

He felt that the minimum low flow specified for which the objectives are to be met has application for point source discharges but in terms of nonpoint sources, the City would favour a joint probability distribution of stream flow and rainfall on a site-specific basis.

With regard to mixing zones, the City felt that these should be handled on a case-by-case basis without guidelines attached, which invariably become the objectives and eventually the applied standards.

Mr. McBride said that, in the domestic consumption category, there is some confusion, since numbers recommended are a mix of finished and raw drinking water. Microbiological levels recommended are those which can be accommodated in a system with plain chlorination. The City concurs that reference to microbiological limits in water quality objectives should be omitted since water treatment technology permits the elimination of pathogenic bacteria from finished water supplies.

In the agricultural use category, the City's contention was that the faecal coliform limit of 1000 per 100 millilitres is unnecessary since it is impossible to control surface contamination from all sources. Public health agencies have opted for proper preparation of food, prior to use, as the means of controlling bacteria.

Mr. McBride also stated that there is no scientific defense for a faecal coliform limit of 1000 per 100 millilitres for secondary body contact recreation.

§ Town of Selkirk

Mr. Andy Dmitruk, supervisor of water and wastewater treatment plants in the Town of Selkirk, in his presentation, asked how the changes proposed in the new management proposal would affect the watershed systems that had already been classified.

Selkirk favoured the separate recreation category in the new document as opposed to the original concept of combining fisheries and recreation. In these terms, the Selkirk representative would like to see the Red River in the Selkirk area reclassified to a primary recreation category, i.e. faecal coliforms less than 200 per 100 millilitres.

Selkirk strongly supported the aims of surface water quality objectives but would like them to be more positive and enforceable, that the objectives should be more like standards than guidelines.

§ Manitoba Department of Health

The representative from the Environmental Health Branch of the Department of Health, Dr. N. S. Rihal, stated that it might be desirable to have different limits for bacteria in agricultural irrigation water, depending on whether a vegetable crop, on which the water is used, is a root crop or has an edible product that is grown above ground. Beyond this, the best bacterial water available should be used as a health protection measure. As a matter of interest, Alberta employs a faecal coliform objective of 200 per 100 millilitres compared to the 1000 per 100 millilitres for application to vegetable crops as proposed for Manitoba. The United States Environmental Protection Agency recommends no irrigation of vegetables with sewage effluent for one month prior to harvest. He pointed out that the Commission order on Roblin with respect to sewage effluent irrigation of forage crops requires that livestock not graze for seven days after sewage effluent application even in circumstances where the faecal coliform content is less than 1000 per 100 millilitres.

§ Manitoba Hydro

The presentation of Manitoba Hydro's submission was made by Mr. Dennis Windsor of the Environmental Services Department and Mr. Bill Brown of the Thermal Generation Department. These representatives reiterated the concern that objectives, once established, seem to be used as legal standards. They were also concerned that numerical changes in the proposal did not appear to reflect Manitoba information.

Another view expressed was that exceedance of the objectives does not always render the water unusable for the predetermined purpose but simply represents a deviation from the most desirable condition. Manitoba

Hydro contended that, under some generating conditions at their thermal plant, cooling water could not meet the objectives. However, a careful review that might indicate that the discharges are occurring without adverse effect on aquatic organisms, should result in objectives that reflect that circumstance (i.e. this was a plea for a case-by-case site-specific study). There was agreement that mixing zones should be established on an individual basis, with the guidelines being omitted from the section.

Mr. Windsor pointed out that Manitoba Hydro is a major user of water for the very important purpose of hydroelectric power generation and that licences and approvals for such use were obtained from a number of regulatory authorities. Such use involves extensive water management and, although these operations are usually noncontaminating, physical components of water quality may be temporarily altered.

Mr. Brown expressed the opinion that the "exceptional" water category could be applied to virtually any surface water since factors aside from water quality considerations were part of the definition. Mr. Brown asked if, for example, under such criteria, Manitoba Hydro could request this designation for a stream, to protect future hydroelectric development potential, to the exclusion of all other users.

A number of problems with the classification document were also raised; however, this document is not a subject of this review.

In terms of the advisory water quality objectives committee which has some responsibility in vetting proposed changes to the water quality objectives, Manitoba Hydro felt that it should have representation on that committee.

Manitoba Hydro also questioned how the objective setting and water quality monitoring program could be effective during a period of limited resources to carry on the program.

In summary, Manitoba Hydro accepted the document as a planning tool; however, they strongly recommended that the objectives that have been set should not be used as control standards since they have no confirmed validity in the Manitoba context. Flexibility in response to individual circumstances was urged since there are too many different water use activities for any single predetermined set of objectives and the classification program contains no means for dealing with the legitimate competing water uses except by the application of water quality considerations as the determing criteria. Other factors such as necessity, economic importance, and land use should also influence the decision making process.

§ Canada Fisheries and Oceans

The Canada Fisheries and Oceans representative, Dr. Lyle Lockhart of the Freshwater Institute, outlined his department's position with respect to water quality.

He noted that the objectives seemed to be directed to a condition of continuous chemical loading to water whereas biological effects in waterways may differ with the time course of releases. The situation with respect to the accumulation of acids in snow and their subsequent release in snow melt seemed not to be covered by the objectives. In his opinion, short-term exposures to higher concentrations should be addressed. There may also be a need to set guidelines for sediments as well as the overlying water column.

With respect to discharges of such substances as hydrocarbons under ice cover, fish kills and tainting could occur whereas in open waters such materials would volatilize. For these and other reasons, it might be desirable to set seasonal objectives.

Dr. Lockhart expressed doubt that there is a recognized manner in which to measure assimilative capacity. In that there is a considerable variation in terms of the LC_{50} of many compounds to differing species of

aquatic life, how was the appropriate LC_{50} value selected. There was also very little information on the toxicity of herbicides to aquatic plants which are an important part of the ecosystem.

An examination of the map of Manitoba showed that only two of the nineteen identified watersheds lie entirely within Manitoba which indicates a need to have common universal guidelines to the greatest extent possible recognizing that different jurisdictions may place different values on the waters of a shared watershed.

Dr. Lockhart stated that there should be a clear statement of the intent of the Department with regard to enforcement of objectives and perhaps of the consequences of noncompliance.

§ Mines Branch

The Director of the Mines Branch, Mr. Bill Bardswich, urged that objectives should not be changed in the midst of a project such as a mining operation since costs including pollution control are built into the initial budget and subsequent changes could result in the project becoming nonviable.

He stated that mines are a nonrenewable resource with a limited life and are extremely important to the socioeconomic base of northern Manitoba. While acknowledging the need for adequate environmental protection, he expressed the view that, in addition to ensuring that we do not create pollution havens, there was a danger of a desire to create a pollution utopia, which might prevent mining development under the real-life, worldwide, competitive conditions that exist.

§ Other Submissions

A number of citizens wanted assurances that surface waters were free of contaminants. Of particular concern were pesticides and nitrates, reaching waters by aerial drift and runoff.

§ Manitoba Department of Agriculture

A brief was presented to the Commission by Mr. Erv Griffin, General Manager of The Manitoba Water Services Board, following the hearing. The Department of Agriculture supported the present concept that current uses identified for a watershed should determine the quality of water which must be maintained.

A number of examples of numerical values were cited that indicated the numbers selected were very protective. Mr. Griffin believes it was essential that good judgement, taking into account economic considerations, be exercised in their application, assuring a sound economic basis in any applied regulation.

The Department of Agriculture, like others, also urged that mixing zones be developed on a case by case basis and that the guidelines for mixing zones be withdrawn from the objectives document.

Mr. Griffin had serious reservations as to whether the un-ionized ammonia level of .02 milligrams per litre (as NH_3) was justified. This could have far reaching economic implications for a city such as Brandon. He recommended that an assimilative capacity study should be undertaken on the Assiniboine River as well as a study to define the mixing zones for Brandon. He indicated that The Manitoba Water Services Board would probably be able to share in the cost of such studies.

§ Saskatchewan Environment

The Saskatchewan Minister of Environment, in correspondence with The Honourable Gerard Lecuyer subsequent to the hearing, noted that there were differences between the Manitoba objectives and the maximum acceptable levels derived by the Committee on Water Quality of the Prairie Provinces Water Board. The Honourable Neal Hardy noted that Manitoba was expected to provide the documentation utilized for the derivation of the Manitoba objectives to the Committee on Water Quality. The Committee, based on this

review and their own understanding of the scientific literature, might then decide to use a number for the maximum acceptable level for a particular constituent that differs from the Manitoba objectives.

§ Revisions to Document Subsequent to Hearing

Staff of the Environmental Management Division reviewed the briefs presented at the hearing and developed a number of revisions based on this examination which are contained as Appendix B.

LIST OF EXHIBITS

1. Environmental Management Division presentation prepared by D. Williamson of Water Standards and Studies.

2. Comments received on the objectives from other jurisdictions as summarized by the Environmental Management Division along with revisions proposed by the Division.

3. Memorandum from the Environmental Management Division concerning the procedure for revising the surface water quality objectives.

4. Brief by Water Quality Branch and Environmental Protection Services of Environment Canada.

5. Brief by Ducks Unlimited Canada.

6. Brief by Manitoba Mining Association.

7. Brief by City of Brandon.

8. Brief by Manitoba Environmental Council.

9. Brief by City of Winnipeg.

10. Brief by Town of Selkirk.

11. Brief by Environmental Health Services.

12. Brief by Manitoba Hydro.

13. Brief by Canada Fisheries and Oceans.

14. Letter from the Rural Municipality of St. Francois Xavier.

15. Presentation from Mrs. D. Doersam.

16. Surface Water Quality Management Proposal, Environmental Management Division, Volume 1 and Volume 2.

17. Report on a Proposal Concerning Surface Water Quality Objectives and Stream Classification, The Clean Environment Commission, May 1979.

18. Canada's Fish Habitat Law - Publication of Canada Fisheries & Oceans.

19. Fish Habitat - The Foundation of Canada's Fisheries - Publication of Canada Fisheries & Oceans.

20. Brief by Manitoba Department of Agriculture.

21. Letter from The Honourable Neal Hardy, Saskatchewan Minister of Environment, to The Honourable Gerard Lecuyer, Manitoba Minister of Environment and Workplace Safety and Health.

APPENDIX B

Changes by Environmental Management Division Subsequent to Hearing

As a result of briefs presented at the hearing, the Environmental Management Division proposed the following revisions.

1. On Page ii, the following new paragraph will be inserted between the presently existing third and fourth paragraphs:

> "Noteworthy is the fact that further information may be required for the appropriate interpretation and implementation of these objectives. This information may include the cause-effect relationships between pollutants and receptors and contaminant transport and fate mechanisms. As well, information may be required to identify if the sensitivity of certain aquatic species or other water uses are unique or to identify if the toxicity or availability of a pollutant is altered at a specific site. This information may be available from the original referenced source documents, other scientific literature or appropriate expert professionals."

2. On Page ii, the last paragraph will be changed to read:

> "Waters may have natural characteristics outside certain objectives. In such cases, the objectives for those characteristics do not apply. These objectives are intended to apply to conditions in water that are caused by man's activities. However, if a certain parameter exceeds its objective due to natural conditions, it would be unwise to further increase that parameter by man-made activities, unless site-specific investigations are conducted."

3. On Page iii, the following will be added to the first paragraph:

> "However, while these objectives are appropriate for most applications within Manitoba, objective modifications may be required at some unique sites. Modifications of objectives could be required for example, to account for the lower or greater sensitivity of resident aquatic species, or to consider the altered availability or toxicity of a pollutant due to the chemical or physical properties of the receiving water, or to reasonably protect other existing uses presently underprotected or overprotected."

4. On Page iv, line 6 of the second paragraph, "that" will be changed to "than".

5. On Page vii, line 4 of Class 4: Agricultural Consumption, "various" will be changed to "variously".

6. On Page viii, the last sentence will be deleted. The last paragraph will now begin "Class 6: Other Uses. Manitoba's surface waters may be . . ."

7. On Page ix, in the Preamble, the third paragraph will be deleted; and the first sentence of the fourth paragraph will be changed to read, "the attached document has been prepared . . ."

8. On Page x, in the Preamble, the telephone number listed for further information will be changed from "944-7030" to "945-7030".

9. On Page 3, the second paragraph will now read:

> "Where water quality could not be defined in quantitative terms due to the lack of scientific information, general narrative statements were developed that reflected the necessary and - desirable quality."

10. On Page 3, Section 1.1, the last sentence of part (a), will be changed to read:

> "The assimilative capacity is usually determined by appropriate modelling techniques or, where possible, through site-specific assimilation studies. Initial dilution calculations are also useful in order to estimate the difference between objective levels and ambient levels, where the ambient concentrations are lower. However, both methods have disadvantages, since, for many contaminants, assimilation modelling techniques have not been accurately developed, and reliance solely upon dilution calculations may result in the transport of certain constituents to other parts of the aquatic ecosystem, where they may accumulate to harmful concentrations."

11. On Page 4, Section 1.1, in the last line of the second paragraph, the word "in" will be changed to "into".

12. On Page 4, Section 1.2, Natural Characteristics Outside the Objectives, the first paragraph will be changed to read as follows:

> "Waters may have natural characteristics outside certain objectives. In such cases, the objectives for those characteristics do not apply."

and the last paragraph of that section will be changed to read as follows:

"It should be noted that where a certain parameter exceeds its objective due to natural conditions, further deterioration by . ."

13. On Page 5, Section 1.2, the last line of the second paragraph will be changed from "site specific" to "site-specific".

14. On Page 5, Section 1.3, the first line of the second paragraph will be changed from "cause effect" to "cause-effect".

15. On Page 5, Section 1.3, the following will be inserted as a new paragraph following the presently existing fourth paragraph:

"Utilization and implementation of these surface water quality objectives requires a thorough knowledge of the cause-effect relationships between pollutants and receptors. Transport mechanisms must be understood in order to determine the ultimate fate of contaminants within the aquatic environment.

Because of the complex nature of this information, it is not possible to include all such material within this document. Further information therefore, may be required, such as from the referenced source documents, scientific literature or appropriate expert professionals."

16. On Page 5, Section 1.3, the following will be added to the existing fifth paragraph:

> "While these water quality objectives are appropriate for most applications within Manitoba, unique conditions may exist at a specific site that would require objective modifications. Modifications of objectives could be required, for example, to account for the lower or greater sensitivity of resident aquatic species, or to consider the altered availability or toxicity of a pollutant due to the chemical or physical properties of the receiving water, or to reasonably protect other existing uses presently underprotected or overprotected."

17. On Page 7, Section 1.5, Exceptional Value Waters, the following will be inserted as the second sentence of the last paragraph:

> "While principal consideration for Exceptional Value designation will be given the above waters, other exceptional value uses, such as domestic consumption, will also be considered."

18. On Page 8, the last line of the first paragraph will be changed to read:

> "Analytical techniques will be developed, when possible, given reasonable information that such substances are present. It should be noted, however, that such analytical methods and objectives development is very costly and time consuming."

19. On Page 9, Section 1.7, General Requirement, the first sentence of the last paragraph will now read:

> "All waters of the Province of Manitoba, such as streams lakes, marshes, swamps, lowlands, etc., should be free . . ."

20. On Page 14, Section 1.8.3, the title of this Section will be changed to read as follows:

"1.8.3 Lakes, Bays, Marshes, Sloughs, Impoundments and Other Wetlands"

The first sentence of this section will now read:

"The surface water quality objectives should apply at all times to lakes, bays, marshes, sloughs, impoundments and other wetlands."

21. On Page 14, Section 19, part (b), the phrase " . . . not more than 25% of the cross-sectional area/volume of flow at any transect . . ." will be changed to read:

" . . . not more than 25% of the cross-sectional area or volume of flow at any transect . . ."

22. On Page 15, Section 2.1, Class 1: Domestic Consumption, the first sentence will now read as follows:

"This class will ensure the protection of waters that are suitable for human consumption, culinary or domestic food processing purposes, and other household purposes."

The second paragraph of that section will now begin:

"The specific requirements listed hereunder are a combination of maximum acceptable concentrations and objective concentrations recommended in the document "Guidelines for Canadian Drinking Water Quality", 1978, published by Health and Welfare Canada, and guidelines utilized by the Province of Manitoba."

23. On Page 23, Cadmium Objectives, Page 25, Lead and Nickel Objectives, the statements immedia-ely following the objective equations will now read:

> "where hardness is expressed in mg/L as $CaCO_3$ and the resultant objective is expressed in µg/L."

24. On Page 37, Sulfate (SO_4), the objective for sulfate will be changed from 1000 mg/L to 600 mg/L.

25. Because of the suggested -evisions received from The Manitoba Water Services Board, transmitted on December 19, 1984, the following revision to the third paragraph on Page ii is also recommended:

> "The objectives are also used by other government agencies as guidelines to assist in determining if certain waters are suitable for uses such as irrigation."